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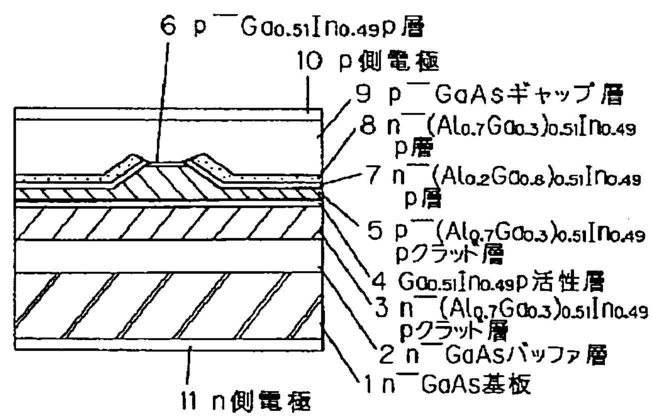
(54)【発明の名称】　半導体レーザおよびその製造方法

(57)【要約】

【目的】　可視光領域に発振波長を有する半導体レーザに関するもので、外部微分量子効率が高く、また横モードの安定性の高い高出力の半導体レーザを提供する。

【構成】　半導体レーザの$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５の一部が台形状のストライプであり、ストライプの外部の$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５上に$n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層７、$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層８を積層した構造を有し、台形状のストライプの内部の実効屈折率がストライプの外部の実効屈折率より０．０２低くなっている。



【特許請求の範囲】

【請求項１】半導体基板、及び該半導体基板上に形成された積層構造であって、活性層と、該活性層を挟む一対のクラッド層と、該活性層のストライプ状所定領域に電流を注入するための電流狭窄層とを有する積層構造、
を備えた半導体レーザであって、
該電流狭窄層は、該活性層の該所定領域に対応する領域以外の領域に形成された第１電流ブロック層を備えており、該第１電流ブロック層は、該一対のクラッド層の屈折率よりも高い屈折率を有する半導体層であって、該活性層の禁制帯幅よりも広い禁制帯幅を有している半導体レーザ。

【請求項２】請求項１に記載の半導体レーザであって、
前記一対のクラッド層のうち、前記活性層よりも上方に位置するクラッド層は、該半導体レーザの共振器方向に沿って延びるストライプ状リッジを有しており、
前記第１電流ブロック層は、該ストライプ状リッジを有する該クラッド層上において、該ストライプ状リッジ以外の領域を覆っている半導体レーザ。

【請求項３】前記電流狭窄層は、前記第１電流ブロック層上に設けられた第２電流ブロック層を更に備えており、
該第２電流ブロック層は、前記活性層の禁制帯幅よりも広い禁制帯幅を有している半導体層である請求項２に記載の半導体レーザ。

【請求項４】前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、台形である請求項３に記載の半導体レーザ。

【請求項５】前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、長方形である請求項３に記載の半導体レーザ。

【請求項６】前記半導体基板は、ＧａＡｓから形成されており、
前記活性層は、ＧａＩｎＰから形成されており、
前記第１及び第２電流ブロック層、ならびに前記一対のクラッド層は、ＡｌＧａＩｎＰから形成されている請求項３に記載の半導体レーザ。

【請求項７】前記活性層は、多重量子井戸構造を有している請求項１に記載の半導体レーザ。

【請求項８】前記一対のクラッド層のうちの一方は、前記第１電流ブロック層を挟みこむ第１層部分及び第２層部分を有している請求項１に記載の半導体レーザ。

【請求項９】前記半導体基板は、ＧａＡｓから形成されており、
前記活性層は、ＩｎＧａＡｓ層を含んでおり、
前記一対のクラッド層は、ＧａＩｎＰから形成されており、
前記第１半導体層は、ＧａＡｓから形成されている請求項８に記載の半導体レーザ。

【請求項１０】前記活性層は、多重量子井戸構造を有している請求項８に記載の半導体レーザ。

【請求項１１】半導体基板上に積層構造を形成する工程を包含する半導体レーザを製造する方法であって、該工程は、更に、
第１クラッド層を形成する工程と、
該第１クラッド層上に活性層を形成する工程と、
該活性層上に第２クラッド層となる膜を形成する工程と、
該膜の一部を選択的にエッチングすることにより、該半導体レーザの共振器方向に延びるストライプ状リッジ部を該膜に形成して、それによって第２クラッド層を形成する工程と、
該第２クラッド層のうち該ストライプ状リッジ部以外の部分の上に、該第２クラッド層の屈折率よりも高い屈折率を有し、かつ、該活性層の禁制帯幅よりも広い禁制帯幅を有している第１半導体層を形成する工程と、
該第１半導体層上に、該活性層の禁制帯幅よりも広い禁制帯幅を有している第２半導体層を形成する工程と、
を包含する半導体レーザの製造方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、発光効率が高く、基本横モードの安定性に優れた高出力の半導体レーザおよびその製造方法に関するものである。

【０００２】

【従来の技術】可視光領域でレーザ発振を生じて発光する半導体レーザは、レーザ・ビーム・プリンターや光ディスク等の光情報処理用光源などの用途があり、最近その重要性を増している。中でも、$(Al_xGa_{1-x})_{0.5}In_{0.5}P$系の材料は、良質の基板材料であるＧａＡｓに対して格子整合し、組成ｘを変化させることで０．６８μｍから０．５６μｍの範囲内の任意の波長を有するレーザ光を得ることができるため注目されている。

【０００３】以下、図１０を参照して従来のダブルヘテロ構造の横モード制御型の赤色領域に発振波長を有する半導体レーザについて説明する。この半導体レーザは、図１０に示すように、ｎ－ＧａＡｓ基板１上にｎ－ＧａＡｓバッファ層２、$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層３、$Ga_{0.51}In_{0.49}P$活性層４、$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５、$p-Ga_{0.51}In_{0.49}P$層６、ｎ－ＧａＡｓ電流ブロック層１３、ｐ－ＧａＡｓキャップ層９をこの順に備えている。そのキャップ層９上にはｐ側電極１０が、また基板１の裏面にはｎ側電極１１が形成されている。

【０００４】この半導体レーザでは、有機金属気相成長法（ＭＯＶＰＥ法）などの結晶成長技術が用いられる。これらの結晶成長技術を用いて、ｎ－ＧａＡｓ基板１上にｎ－ＧａＡｓバッファ層２、$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層３、$Ga_{0.51}In_{0.49}P$活性層４、$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド

層5およびp $Ga_{0.51}In_{0.49}P$層6を順次堆積する。

【0005】次にホトリソグラフィー技術とエッチング技術により、p $Ga_{0.51}In_{0.49}P$層6とp $(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層5とを台形状にエッチングしてストライプ状リッジをクラッド層5に形成する。その後MOVPE法などを用いてn GaAs電流ブロック層13をストライプの外部に選択的に堆積し、さらにp－GaAsキャップ層9を堆積する。

【0006】このような半導体レーザの構造では、n GaAs電流ブロック層13により電流の狭窄を行うことができ、またp－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層5を台形上にエッチングする際に、台形の高さ及び幅を最適化することにより、単一横モードの条件を満足する実効屈折率差を台形状のストライプの内外でつけることができ、活性層4のうち、クラッド層5のストライプ状リッジ下部に光を効果的に閉じこめることができる。ストライプの幅は典型的には約5μmである。

【0007】

【発明が解決しようとする課題】ところが、従来例の構造では、電流ブロック層として、活性層よりも禁制帯幅が小さいGaAsを用いている。このため、このGaAs層が光の吸収層として働く。そのために、吸収による光の損失が大きく、半導体レーザの共振器内を光が導波する時の導波損失α_iが約15cm^{-1}と大きくなる。その結果、半導体レーザの外部微分量子効率が約60％と小さくなる。また、この半導体レーザではキンク・レベルは約12mWと小さい。キンクは横モードが変化することにより生じるが、図10の構造では基本モードと高次のモードとの利得の差がさほど大きくなく、注入電流の増加により容易にモードが変化しやすくなるためである。外部微分量子効率が小さく、基本横モードの安定性が低いことから、従来例の構造では高い光出力を持つ半導体レーザが得にくい。

【0008】この発明の目的は、このような課題を解決し、高い外部微分量子効率を有する、基本横モードの安定性の高い、高出力の半導体レーザおよびその製造方法を提供することである。

【0009】

【課題を解決するための手段】本発明の半導体レーザは、半導体基板、及び、該半導体基板上に形成された積層構造であって、活性層と、該活性層を挟む一対のクラッド層と、該活性層のストライプ状所定領域に電流を注入するための電流狭窄層とを有する積層構造、を備えた半導体レーザであって、該電流狭窄層は、該活性層の該所定領域に対応する領域以外の領域に形成された第1電流ブロック層を備えており、該第1電流ブロック層は、該一対のクラッド層の屈折率よりも高い屈折率を有する半導体層であって、該活性層の禁制帯幅よりも広い禁制帯幅を有しており、そのことにより、上記目的が達成される。

【0010】ある実施例では、前記一対のクラッド層のうち、前記活性層よりも上方に位置するクラッド層は、該半導体レーザの共振器方向に沿って延びるストライプ状リッジを有しており、前記第1電流ブロック層は、該ストライプ状リッジを有する該クラッド層上において、該ストライプ状リッジ以外の領域を覆っている。

【0011】ある実施例では、前記電流狭窄層は、前記第1電流ブロック層上に設けられた第2電流ブロック層を更に備えており、該第2電流ブロック層は、前記活性層の禁制帯幅よりも広い禁制帯幅を有している半導体層である。

【0012】ある実施例では、前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、台形である。

【0013】ある実施例では、前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、長方形である。

【0014】ある実施例では、前記半導体基板は、GaAsから形成されており、前記活性層は、GaInPから形成されており、前記第1及び第2電流ブロック層、ならびに前記一対のクラッド層は、AlGaInPから形成されている。

【0015】前記一対のクラッド層のうちの一方は、前記第1電流ブロック層を挟みこむ第1層部分及び第2層部分を有していてもよい。

【0016】ある実施例では、前記半導体基板はGaAsから形成されており、前記活性層はInGaAs層を含んでおり、前記一対のクラッド層はGaInPから形成されており、前記第1半導体層はGaAsから形成されている。

【0017】前記活性層は、多重量子井戸構造を有していてもよい。本発明の半導体レーザの製造方法は、半導体基板上に積層構造を形成する工程を包含する半導体レーザを製造する方法であって、該工程は、第1クラッド層を形成する工程と、該第1クラッド層上に活性層を形成する工程と、該活性層上に第2クラッド層となる膜を形成する工程と、該膜の一部を選択的にエッチングすることにより、該半導体レーザの共振器方向に延びるストライプ状リッジ部を該膜に形成して、それによって第2クラッド層を形成する工程と、該第2クラッド層のうち該ストライプ状リッジ部以外の部分の上に、該第2クラッド層の屈折率よりも高い屈折率を有し、かつ、該活性層の禁制帯幅よりも広い禁制帯幅を有している第1半導体層を形成する工程と、該第1半導体層上に、該活性層の禁制帯幅よりも広い禁制帯幅を有している第2半導体層を形成する工程と、を包含しており、そのことにより上記目的が達成される。

【0018】

【作用】本発明の電流狭窄層は、活性層のストライプ状

所定領域に対応する領域以外の領域に形成された第１電流ブロック層を備えている。この第１電流ブロック層は、一対のクラッド層の屈折率よりも高い屈折率を有し、かつ、該活性層の禁制帯幅よりも広い禁制帯幅を有している。

【００１９】第１電流ブロック層は、電流が活性層に流れ込むことを阻止する機能を有する。このため、第１電流ブロック層が存在しない領域に対応する活性層の所定領域にのみ、電流が選択的に注入される。その結果、活性層のストライプ状所定領域においてのみレーザ光が発生する。このレーザ光の一部は、活性層から上下方向にもれ、クラッド層及び第１電流ブロック層に達する。第１電流ブロック層は、活性層の屈折率よりも高い屈折率を有しているため、レーザ光は、ストライプ状の所定領域から横方向へ漏れる。この理由は、一般に、光は屈折率の高い領域に集まるからである。

【００２０】基本水平横モードにて発振するレーザ光と、高次の水平横モードにて発振するレーザ光とを比較して場合、高次の水平横モードにて発振するレーザ光の方は、横方向により広く分布している。このため、本発明の半導体レーザにおいては、高次の水平横モードにて発振するレーザ光の方が、基本水平横モードにて発振するレーザ光よりも、ストライプ状の所定領域から横方向へ漏れる程度が強い。このため、高次の水平横モードにて発振するレーザ光は発散し、レーザ発振に寄与しなくなる。言い替えると、第１電流ブロック層の存在によって、高次の水平横モードにて発振するレーザ光は、基本水平横モードにて発振するレーザ光に比較して、より高い閾値利得を有することとなる。その結果、基本水平横モードにて発振するレーザ光のみを選択的に得ることができる。

【００２１】また、第１電流ブロツク層が活性層の禁制帯幅よりも広い禁制帯幅を有しているため、活性層で発生したレーザ光は第１電流ブロック層に吸収されない。このため、従来の半導体レーザに比較して、レーサ光の伝播損失が低減される。

【００２２】以上説明したように、本発明の半導体レーザは、基本水平横モードのレーザ光を低い伝播損失にて発振させることができる。

【００２３】

【実施例】（実施例１）以下、この発明の実施例を図面を参照しながら説明する。

【００２４】図１にこの発明の一実施例の横モード制御型の赤色半導体レーザの断面図を示す。

【００２５】この半導体レーザは、図１に示すように、例えばｎ－ＧａＡｓ基板１上にｎ－ＧａＡｓバッファ層２を介して$Ga_{0.51}In_{0.49}P$活性層４（厚さ６００オングストローム）を$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層３および$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５で挟むダブルヘテロ構造を有している。$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５の上部には、$p-Ga_{0.51}In_{0.49}P$層６（厚さ１０００オングストローム）を有し、$p-Ga_{0.51}In_{0.49}P$層６および$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５の一部は、台形状のストライプ状リッジに加工されている。クラッド層５においてストライプ状リッジ部分の厚さは１．３μｍ、ストライプ状リッジ部分以外の部分の厚さは0.25μｍである。

【００２６】ストライプ状リッジの両脇の$p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層５の上には、７００Åの$n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層７と０．７μｍの$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層８が堆積されている。さらに、$p-Ga_{0.51}In_{0.49}P$層６および$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層８の上部には、ｐ－ＧａＡｓキャップ層９を有している。

【００２７】上記ストライプ状リッジの幅は基本横モードと高次のモードとの利得の差を大きくとれるような幅になっており、その幅は約７μｍがよい。７μｍよりも極端に細い場合、例えば約２μｍの場合には、ストライプ外への光の漏洩が大きくなりすぎて、レーザ発振に寄与しない光が増加して、しきい値電流の上昇や、損失が大きくなって外部微分量子効率の低下をもたらす。また、ストライプ幅が大きくなりすぎると、基本横モードと高次のモードとの利得の差が小さくなったり、$Ga_{0.51}In_{0.49}P$活性層４へのキャリアの注入の不均一が水平方向で生じ、キンク・レベルの低下が発生して、実用に耐えない。

【００２８】また本実施例ではストライプ状リッジの断面形状は台形であるが、この断面形状は長方形であってもよい。その場合、リッジの側面上には層７および８を形成しないことが望ましい。

【００２９】この半導体レーザの各層の構成によって決まる水平方向の実効屈折率を図２に示す。ストライプ状リッジの内部の実効屈折率は３．３０７、ストライプ状リッジの外部の実効屈折率は３．３２９であり、外部の方が０．０２２高い。この実効屈折率差は７００Åの$n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層７と０．７μｍの$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層８によってもたらされている。この実効屈折率差のために基本横モードと高次のモードとの間に大きな利得の差が生じる。このため、注入電流の量を大きくしてもキンクが発生しにくいので、キンクの無い状態で高い光出力を得ることができる。

【００３０】ここで$n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層７と$n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層８によってもたらされた実効屈折率差のために、基本モードと高次モードとの間に大きな利得の差が生じていることを図１１に示す。図１１は、横軸にストライプ幅、縦軸にしきい値利得g_{th}をとったものである。この図に基本モード（ｍ＝０）と、高次モードとして１次モード

（m＝1）とのしきい値利得の差を（a）本発明、（b）従来例のそれぞれについて記載した。この図11からわかるように、（b）の従来例のレーザは、基本モードと1次モードとのしきい値利得の差が小さく1次モードのような高次モードが生じやすい。これに対して本発明のレーザ（b）は、基本モードと1次モードとのしきい値利得の差が大きく、1次モードのような高次モードは生じにくい。

【0031】図14は、本発明の半導体レーザについて、駆動電流（CURRENT）と光出力（OUTPUT POWER）との関係を示している。このグラフに示されているデータは、出射端面が反射率6％の膜によってコーテイングされ、他の端面が反射率83％の膜によってコーテイングされた半導体レーザについて得られた。半導体レーザの共振器長は500μである。光出力が約65mWを越えるまで、光出力は駆動電流の増加に従って直線的に増加しているが、光出力が約65mWを越えた後、光出力の増加の程度は一時的に低下する。前述したように、グラフにおいて、そのような部分を「キンク」という。キンクが発生するのは、光出力があるレベル以下にあるとき、基本モード（m＝1）にあるレーザ光だけが発振していたのが、光出力がそのレベル（「キンクレベル」という）を越えると、基本モード以外のモード（高次のモード：m≧2）にあるレーザ光と基本モードにあるレーザ光とが混在しはじめるためである。キンクレベルが高い半導体レーザほど、基本モードにあるレーザ光を高い光出力にて安定して供給することができる。基本モード（m＝1）にあるレーザ光についての閾値利得と他のモード（m≧2）にあるレーザ光についての閾値利得との差が大きいほど、キンクレベルは高くなる。

【0032】図15は、図1に示す構造を有する本発明の半導体レーザについて、クラッド層4のストライプリッジの幅と、キンクの発生する光出力のレベルとの関係を示すグラフである。

【0033】測定のために使用した半導体レーザの共振器長はいずれも350μmで、各半導体レーザの両端面には反射膜等はコーティングされていない。図15からわかるように、本発明の半導体レーザは、従来の半導体レーザに比較して、キンクレベルが高い。このことは、本発明の半導体レーザにおいて、基本モード（m＝1）の閾値利得と他のモード（m≧2）の閾値利得との差が、従来の半導体レーザにおけるよりも大きいことを示している。

【0034】また、n－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7とn－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層8とは、p側電極10から流れる電流をブロックし、クラッド層5のストライプ状リッジ内に電流を狭窄し、それによって活性層4の所定の領域に電流を注入する働きも具備している。

【0035】本発明では、台形状のストライプの内外に屈折率差を設ける目的で、700Åのn－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7と0．7μmのn－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層8の2種類の半導体層を用いている。1層目の半導体層、すなわちn－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7の屈折率は、p－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層5の屈折率より大きい。2層目にはクラッド層とほぼ屈折率の等しいn－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層8を用いている。光は活性層4の近傍の材料のみの屈折率の影響を受ける。ストライプの外部で安定な実効屈折率を得ることができる。所望のストライプ内外での実効屈折率差は、n－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7の厚さを変化させることで容易に得られる。すなわち、n－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7が厚くなると実効屈折率差は大きくなり、薄くなると小さくなる。そのストライプ内外での屈折率差は、n－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7の厚みの調整により、0.01～0.05の範囲で制御される。

【0036】また、ここでは第1層目のAl組成を0．2としたが、このAl組成を変化させても実効屈折率差を変化させることができる。すなわち、Al組成が小さくなると実効屈折率差は大きくなり、Al組成が大きくなると実効屈折率差は小さくなる。

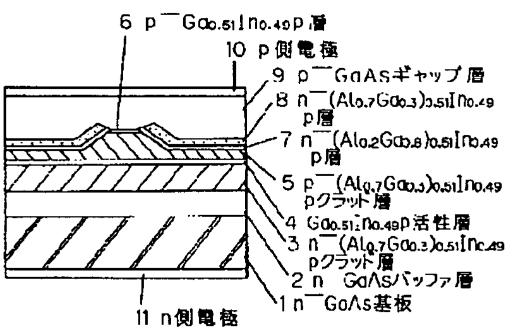
【0037】1種類のみの半導体層で同様の実効屈折率差をつけるためには、屈折率がp－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$クラッド層5のそれより高く、かつ非常に近い材料、例えば、n－$(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}P$層を組成の揺らぎが無く均一に、しかも厚く、例えば1μm以上堆積する必要がある。この場合、n－$(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}P$層の中へ光が深くもれるため、光は活性層4から遠く離れた場所での屈折率の影響を受ける。またn－$(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}P$層の組成すなわち屈折率が、設定値からずれると、ストライプの内外での実効屈折率がずれたりする。またその厚さが薄かったら、$Ga_{0.51}In_{0.49}P$活性層4で生じた光がp－GaAsキャップ層9によって吸収されて、光エネルギーの損失が生じる。したがって、半導体レーザを作製する時の安定性、再現性が低くなる恐れが生じる。所望の実効屈折率差を正確に、再現性よく作るためには2種類以上の半導体層を設けることが好ましい。

【0038】この半導体レーザの光出力と半導体レーザに注入した電流の関係を図3に示す。この半導体レーザでは約30mWまでキンクが無い状態で光出力を得ることができる。また、この半導体レーザの外部微分量子効率η_dは85％と高い。それは、水平方向の実効屈折率差をつけるために、n－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P$層7とn－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P$層8を用いているためである。この2層の禁制帯幅はGa

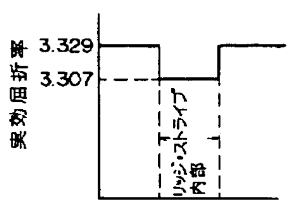
【図9】本発明の半導体レーザの製造工程を表す第5の工程順断面図
【図10】従来例の赤色半導体レーザの断面図
【図11】本発明と従来例の基本モードと1次モードのしきい値利得の差を説明する図
【図12】本発明の半導体レーザの遠視野像を示す図
【図13】本発明の半導体レーザの各層に水平な方向の遠視野像を示す図
【図14】本発明の半導体レーザの特性を示す図で、出射端面に反射率6％のコーティング膜を、他の端面に83％のコーティング膜を設けた半導体レーザの駆動電流と光出力の関係を示す図
【図15】本発明の半導体レーザについて、ストライプ幅とキンクを発生する光出力の関係を示す図
【図16】本発明の別の実施例の横モード制御型の半導体レーザの断面図

【符号の説明】
1　n－GaAs基板
2　n－GaAsバッファ層
3　n－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$Pクラッド層
4　$Ga_{0.51}In_{0.49}$P活性層
5　p－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$Pクラッド層
6　p－$Ga_{0.51}In_{0.49}$P層＊
＊7　n－$(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}$P層
8　n－$(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$P層
9　p－GaAsキャップ層
10　p側電極
11　n側電極
12　SiO_2
13　n－GaAs電流ブロック層
61　n－GaAs基板
62　n－$Ga_{0.51}In_{0.49}$Pクラッド層
63　GaAs光閉じ込め層
64　歪量子井戸活性層
64a　$In_{0.2}Ga_{0.8}$Asウエル層
64b　GaAsバリア層
64c　$In_{0.2}Ga_{0.8}$Asウエル層
65　GaAs光閉じ込め層
66　p－$Ga_{0.51}In_{0.49}$Pクラッド層
66a　光閉じ込め層に接する第1層部
66b　p－GaAsキャップ層68に接する第2層部
67　n－GaAs電流ブロック層
68　p－GaAsキャップ層
69　p側電極
70　n側電極

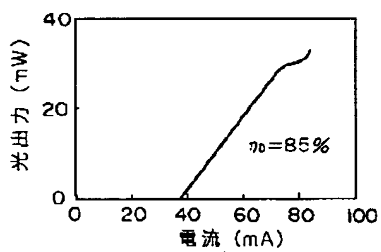
【図1】



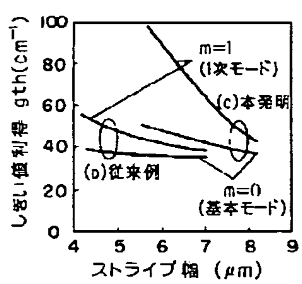
【図2】



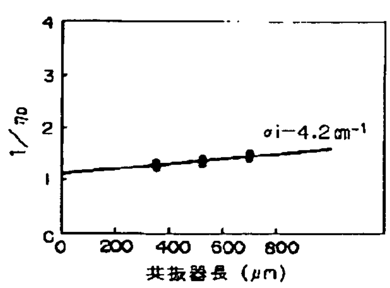
【図3】



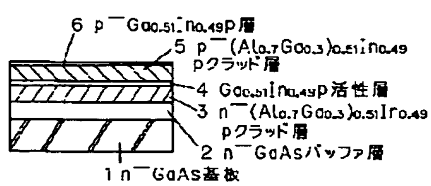
【図11】



【図4】



【図5】



$l_{0.45}Ga_{0.55})_{0.51}In_{0.49}P$光閉じ込め層（厚さ10nm）によって、挟まれる。

【0053】（実施例2）図16を参照して、本発明による他の半導体レーザを説明する。

【0054】この半導体レーザは、n－GaAs基板61、及びn－GaAs基板61上に形成された積層構造を有している。積層構造は、n－GaAs基板61に近い側から順番に、n－$Ga_{0.51}In_{0.49}P$第1クラッド層（厚さ：1.5μm）62、GaAs第1光閉じ込め層（厚さ：0.01μm）63、歪量子井戸活性層64、GaAs第2光閉じ込め層（厚さ：0.01μm）65、p－$Ga_{0.51}In_{0.49}P$第2クラッド層66、n－GaAs電流ブロック層（厚さ：0.15μm）67、p－GaAsキャップ層（厚さ：3μm）68を含んでいる。積層構造のp－GaAsキャップ層68上には、p側電極69が設けられており、n－GaAs基板61の裏面には、n側電極70が設けられている。

【0055】歪量子井戸活性層64は、$In_{0.2}Ga_{0.8}As$第1ウェル層（厚さ：7nm）64a、GaAsバリア層（厚さ：10nm）64b及び$In_{0.2}Ga_{0.8}As$第2ウェル層（厚さ：7nm）64cが形成する量子井戸構造を有している。

【0056】p－$Ga_{0.51}In_{0.49}P$第2クラッド層66は、光閉じ込め層に接する第1層部分（厚さ：0.2μm）66aと、p－GaAsキャップ層68に接する第2層部分（厚さ：1.5μm）66bとに分かれている。p－$Ga_{0.51}In_{0.49}P$第2クラッド層66の第1層部分66aと第2層部分66bとの間に、n－GaAs電流ブロック層67が位置している。

【0057】n－GaAs電流ブロック層67は、歪量子井戸活性層64のストライプ状の所定領域（電流注入領域）に対応する領域以外の領域に形成されている。言い替えると、n－GaAs電流ブロック層67は、歪量子井戸活性層64の電流注入領域に対応する領域にストライプ状の開口部を有している。開口部の幅Wが電流注入領域の幅を規定している。この幅wは典型的には6μmであるが、約3μmから約8μmの範囲において種々の値が選択され得る。n－GaAs電流ブロック層64は、p－$Ga_{0.51}In_{0.49}P$第2クラッド層66の屈折率よりも高い屈折率を有し、かつ、活性層64の禁制帯幅よりも広い禁制帯幅を有している。

【0058】p－$Ga_{0.51}In_{0.49}P$第2クラッド層66の第1層部分66aの厚さh、及びn－GaAs電流ブロック層67の厚さdを調整することにより、ストライプ状電流注入領域の内外での実効屈折率差を制御することができる。p－$Ga_{0.51}In_{0.49}P$第2クラッド層66の第1層部分66aの厚さは、約0.05μmから約0.5μmの範囲において選択され得、n－GaAs電流ブロック層67の厚さは、約0.02μmから約0.5μmの範囲内で選択され得る。

【0059】本実施例の半導体レーザにおいても、前述した構造を有する本発明の半導体レーザと同様の効果が得られる。

【0060】上記クラッド層としては、$Al_xGa_{1-x}As$（0.2≦x≦0.7）層または$(Al_xGa_{1-x})_{0.51}In_{0.49}P$（0≦x≦1）層を用いてもよい。$(Al_xGa_{1-x})_{0.51}In_{0.49}P$（0≦x≦1）層をクラッド層に使用した場合、活性層とクラッド層との間のヘテロ障壁の高さを、本実施例における高さよりも高くすることが可能となる。このため、そのようなクラッド層を採用することにより、より高温で安定に動作し得る半導体レーザが提供される。

【0061】

【発明の効果】本発明の半導体レーザによれば、

（1）半導体レーザのクラッド層のストライプの外部に、上記クラッド層より屈折率が高く、かつ活性層の禁制帯幅よりも広い半導体層を少なくとも具備するために、吸収による光の損失が小さいことから導波損失を小さくでき、外部微分量子効率が高く、また基本横モードの安定性の高い高出力の半導体レーザを得ることができる。

【0062】本発明の半導体レーザの製造方法によれば、

（2）半導体基板上に第1クラッド層、活性層、第2クラッド層を順次積層する工程と、第2クラッド層の一部を台形状のストライプに加工する工程と、該ストライプの外部の第2クラッド層上に、電流の注入を阻止するために少なくとも2種類以上の半導体層を積層する工程を有し、前記2種類以上の半導体層が異なる屈折率を有することから、光の導波損失を小さくすることができ、外部微分量子効率が高く、また基本横モードの安定性の高い高出力の半導体レーザを容易に再現性よく作製することができる。

【図面の簡単な説明】

【図1】本発明の実施例の横モード制御型の赤色半導体レーザの断面図

【図2】本発明の実施例の半導体レーザの層に水平方向の実効屈折率を表す図

【図3】本発明の実施例の半導体レーザの光出力と電流の関係を示す図

【図4】本発明の効果を説明するための図で、外部微分量子効率の逆数$1/\eta_d$と共振器長の関係を示す図

【図5】本発明の半導体レーザの製造工程を表す第1の工程順断面図

【図6】本発明の半導体レーザの製造工程を表す第2の工程順断面図

【図7】本発明の半導体レーザの製造工程を表す第3の工程順断面図

【図8】本発明の半導体レーザの製造工程を表す第4の工程順断面図

$_{0.51}$In$_{0.49}$P活性層4のそれよりも大きい。そのために、Ga$_{0.51}$In$_{0.49}$P活性層4で発生した光は吸収されることがなく、したがって導波損失α_iは小さく、その結果高い外部微分量子効率を得ることができる。図4は導波損失を調べるための実験結果で、外部微分量子効率の逆数1／η_Dと半導体レーザの共振器長の関係を示す図である。1／η_Dと共振器長の間には比例関係があり、この傾きから導波損失は4．2cm^{-1}と導出できる。従来例の半導体レーザの導波損失は約15cm^{-1}であるから、本発明の半導体レーザは1／3～1／4の値をとることになる。したがって、本発明の半導体レーザの外部微分量子効率が高いことが説明できる。

【0039】つぎに本発明の半導体レーザが良好な特性をもつことの説明として、本発明の遠視野像を測定した結果を図12に示す。

【0040】（a）は半導体レーザの各層に水平な方向の角度に対する出力光の強度分布であり、（b）は各層に垂直な方向の角度に対する出力光の強度分布を示している。

【0041】（a）の各層に水平方向の遠視野像のメインのピークの横に小さなサイド・ロブが見られる。このサイド・ロブは本発明の半導体レーザの特徴であるが、この半導体レーザが高次モードで発振しているということではなく、リッジ・ストライプの外にもれた光のためによる。

【0042】このように、本発明の半導体レーザは、その遠視野像からともに基本モードで発振していることがわかる。

【0043】なお、図12に示したメインのピークとサイド・ロブをわかりやすく説明したのが図13である。半導体レーザの各層に水平な方向の光の強度分布である。

【0044】以上述べたように、高い基本横モード安定性と高い外部微分量子効率から、高出力の半導体レーザを得ることができる。

【0045】つぎに、この半導体レーザの作製方法を図5から図9を用いて説明する。まず、MOVPE法などの結晶成長方法を用いて、n－GaAs基板1上にn－GaAsバッファ層2、n－(Al$_{0.7}$Ga$_{0.3}$)$_{0.51}$In$_{0.49}$Pクラッド層3、Ga$_{0.51}$In$_{0.49}$P活性層4、p－(Al$_{0.7}$Ga$_{0.3}$)$_{0.51}$In$_{0.49}$Pクラッド層5、p－Ga$_{0.51}$In$_{0.49}$P層6をエピタキシャル成長する（図5）。SiO$_2$12をp－Ga$_{0.51}$In$_{0.49}$P層6上に堆積させた後、ホトリソグラフィー技術とエッチング技術を用いて、SiO$_2$12とp－Ga$_{0.51}$In$_{0.49}$P層6とp－(Al$_{0.7}$Ga$_{0.3}$)$_{0.51}$In$_{0.49}$Pクラッド層5の一部を台形状のストライプに加工する（図6）。台形状に加工した後、MOVPE法の選択成長技術を用いて、電流ブロック層としてn－(Al$_{0.2}$Ga$_{0.8}$)$_{0.51}$In$_{0.49}$P層7とn－(Al$_{0.7}$Ga$_{0.3}$)$_{0.51}$In$_{0.49}$P層8をSiO$_2$12上に堆積させることなく、ストライプの両脇のp－(Al$_{0.7}$Ga$_{0.3}$)$_{0.51}$In$_{0.49}$Pクラッド層5上に結晶成長させる（図7）。その後、SiO$_2$12を除去し、p－GaAsキャップ層9を結晶成長させる（図8）。最後にp－GaAsコンタクト層9上にCr／Pt／Auを堆積してp側電極10とし、n－GaAs基板1上にAu／Ge／Niを堆積してn側電極11とする（図9）。

【0046】このような製造方法により、図1に示すような横モード制御型の赤色半導体レーザを作製することができる。

【0047】なお、本実施例では台形状のストライプの内外に実効屈折率差を設けるために、2種類の半導体層を用いて説明したが、3種類以上用いても実効屈折差を作ることができる。

【0048】上記実施例では台形状のストライプの内部の実効屈折率をストライプの外部のそれよりも、0．022低くしてあるが、この実効屈折率差は0．01から0．05の範囲であれば、本発明の効果は大きい。ただし、実効屈折率差が変われば、それに合わせて、台形状のストライプ幅も変化させなくてはならない。

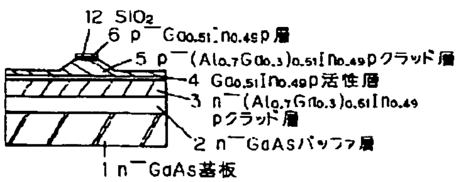
【0049】なおクラッド層5のストライプ状リッジ外部の厚さh、および層7の厚さを変化させることによりストライプ状リッジの外の部分の実効屈折率を制御することができる。hの厚さの範囲は0．05～0．5μm、層7の厚さの範囲は0．02～0．5μm、層8の厚さの範囲は0．3～1μmが好ましい。

【0050】上記実施例では半導体レーザを構成する材料を指定したが、クラッド層が(Al$_y$Ga$_{1-y}$)$_{0.51}$In$_{0.49}$P、活性層が(Al$_z$Ga$_{1-z}$)$_{0.51}$In$_{0.49}$P（ここで、$0 \leqq z \leqq y \leqq 1$）の場合でも、外部微分量子効率が大きく、横モード安定性の高い、高出力の半導体レーザを容易に作製することができる。

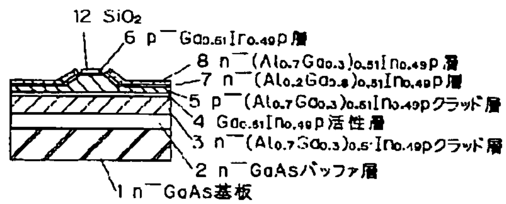
【0051】また、上記実施例では材料にAlGaInPを用いた半導体レーザについて説明したが、他の材料でも本発明の効果が大きいことは言うまでもない。III－V族の半導体レーザのみならず、II－VI族の材料から成る半導体レーザでもこの発明の効果は大きい。

【0052】上記実施例の活性層は、AlGaInP半導体の単層によって形成されているが、多重量子井戸構造を有する活性層が使用され得る。そのような活性層としては、例えば、、Ga$_{0.44}$In$_{0.56}$Pウェル層（厚さ8nm）、(Al$_{0.45}$Ga$_{0.55}$)$_{0.51}$In$_{0.49}$Pバリア層（厚さ5nm）、Ga$_{0.44}$In$_{0.56}$Pウェル層（厚さ8nm）、(Al$_{0.45}$Ga$_{0.55}$)$_{0.51}$In$_{0.49}$Pバリア層（厚さ5nm）、及び、Ga$_{0.44}$In$_{0.56}$Pウェル層（厚さ8nm）含んだ活性層を使用してもよい。このような活性層は、3つのウェル層に0．5%の圧縮歪が生じているため、歪多重量子井戸活性層と呼ばれる。この多重量子井戸活性層は、クラッド層に接する一対の（A

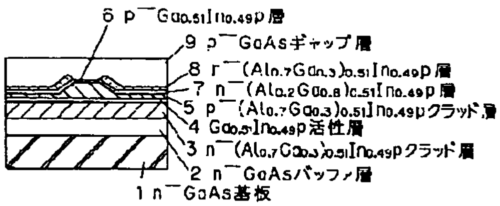
【図6】



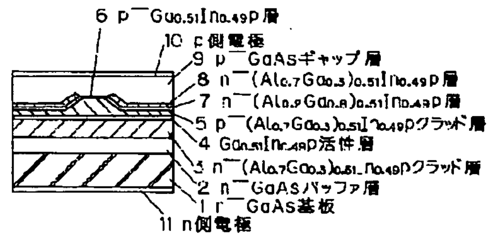
【図7】



【図8】



【図9】



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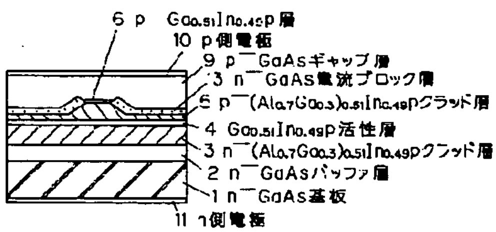
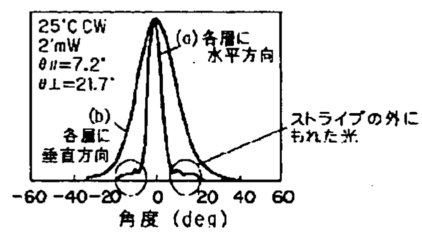
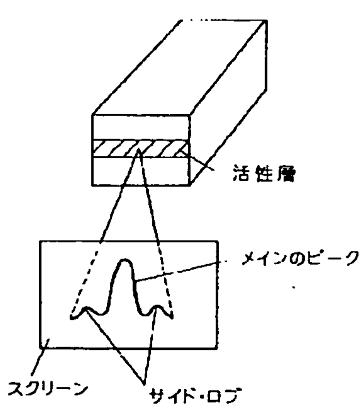


【図12】



【図13】



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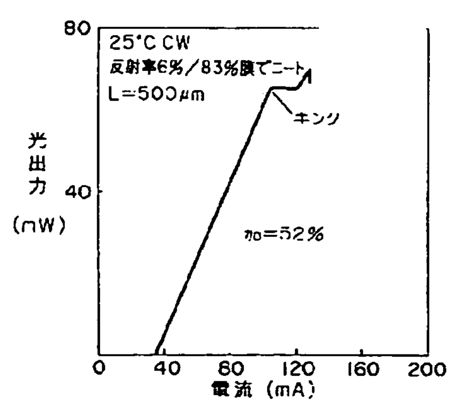

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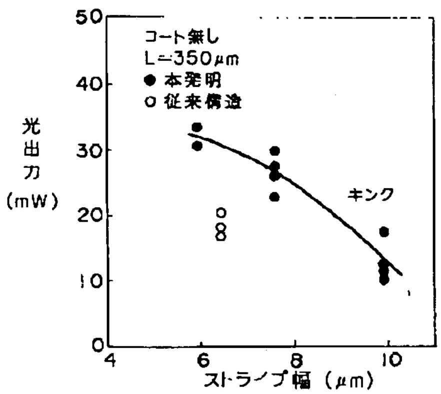
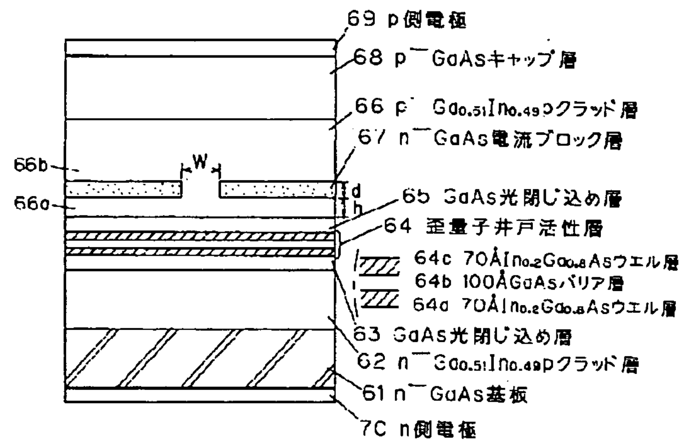

コート無し
L=350μm
● 本発明
○ 従来構造
光出力 (mW)
ストライプ幅 (μm)
キンク
0
10
20
30
40
50
4
6
8
10

【図16】


69 p側電極
68 p⁻ GaAsキャップ層
66 p⁻ Ga0.51In0.49Pクラッド層
67 n⁻ GaAs電流ブロック層
66b
66a
W
d
h
65 GaAs光閉じ込め層
64 歪量子井戸活性層
64c 70ÅIn0.2Ga0.8Asウエル層
64b 100ÅGaAsバリア層
64a 70ÅIn0.2Ga0.8Asウエル層
63 GaAs光閉じ込め層
62 n⁻ Ga0.51In0.49Pクラッド層
61 n⁻ GaAs基板
70 n側電極

Abstract B2

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KAMIYAMA SATOSHI
ONAKA SEIJI

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Priority number :	Priority date :	Priority country :
04189074	16.07.1992	JP
04285740	23.10.1992	JP

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(54) SEMICONDUCTOR LASER AND FABRICATION THEREOF

(57)Abstract:

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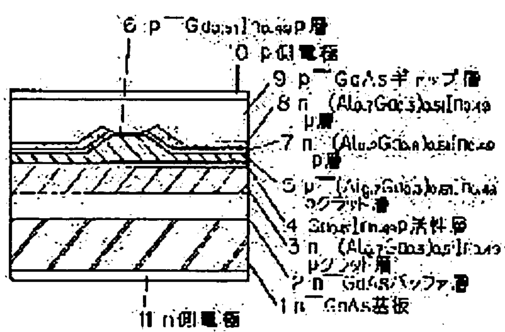
CONSTITUTION: A p-(Al0.7Ga0.3)0.51In0.49 clad layer 5 of semiconductor laser is partially formed into a trapezoidal stripe. An n-(Al0.2Ga0.8)0.51In0.49P layer 7 and an n-(Al0.7Ga0.3)0.51In0.49P layer 8 are deposited on a p-(Al0.7Ga0.3)0.51In0.49P clad layer 5 on the outside of the stripe. Effective refractive index in the trapezoidal stripe is set lower by 0.02 than that on the outside of the stripe.



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CLAIMS

[Claim(s)]

[Claim 1] It is the laminated structure formed on the semiconductor substrate and this semiconductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the clad layer of the couple which sandwiches this barrier layer, and a current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. this current constriction layer It has the 1st-current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. this 1st-current block layer Semiconductor laser which is the semiconductor layer which has a refractive index higher than the refractive index of the clad layer of this couple, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[Claim 2] It is the semiconductor laser to which the clad layer which is semiconductor laser according to claim 1, and is located among the clad layers of the aforementioned couple more nearly up than the aforementioned barrier layer has the stripe-like ridge prolonged along the orientation of a resonator of this semiconductor laser, and the aforementioned 1st-current block layer has covered fields other than this stripe-like ridge on this clad layer that has this stripe-like ridge.

[Claim 3] The aforementioned current constriction layer is semiconductor laser according to claim 2 which is the semiconductor layer which is further equipped with the 2nd-current block layer prepared on the aforementioned 1st-current block layer, and has the forbidden-band width of face with this 2nd-current block layer larger than the forbidden-band width of face of the aforementioned barrier layer.

[Claim 4] Semiconductor laser according to claim 3 whose cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a trapezoid.

[Claim 5] Semiconductor laser according to claim 3 whose cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a rectangle.

[Claim 6] It is the semiconductor laser according to claim 3 in which the aforementioned semiconductor substrate is formed in from GaAs, the aforementioned barrier layer is formed in from GaInP, and the above 1st, the 2nd-current block layer, and the clad layer of the aforementioned couple are formed from AlGaInP.

[Claim 7] The aforementioned barrier layer is semiconductor laser according to claim 1 which has multiplex quantum well structure.

[Claim 8] One side of the clad layers of the aforementioned couple is semiconductor laser according to claim 1 which has the 1st layer fraction and the 2nd layer fraction which are crowded on both sides of the aforementioned 1st-current block layer.

[Claim 9] It is the semiconductor laser according to claim 8 in which the aforementioned semiconductor substrate is formed in from GaAs, the aforementioned barrier layer contains InGaAs layer in, the clad layer of the aforementioned couple is formed in from GaInP, and the aforementioned 1st semiconductor layer is formed from GaAs.

[Claim 10] The aforementioned barrier layer is semiconductor laser according to claim 8 which has multiplex quantum well structure.

[Claim 11] It is the technique of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semiconductor substrate. this process Furthermore, the process which forms the 1st clad layer, the process which forms a barrier layer on this 1st clad layer, the process which forms the layer used as the 2nd clad layer on this barrier layer, and a part of this layer by etching alternatively The stripe-like ridge section prolonged in the orientation of a resonator of this semiconductor laser is formed in this layer. Among the process which forms the 2nd clad layer by it, and this 2nd clad layer, on fractions other than this stripe-like ridge section The process which forms the 1st semiconductor layer which has a refractive index higher than the refractive index of this 2nd clad layer, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The manufacture technique of the semiconductor laser which includes the process which forms the 2nd semiconductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semiconductor layer.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001] [Field of the Invention] It is related with the semiconductor laser and its manufacture technique of the high power which luminous efficiency of this invention was [high power] high and was excellent in the stability of the basic transverse mode.

[0002] [Description of the Prior Art] The semiconductor laser which produces a laser oscillation and emits light in a light field has the intended use of the light sources for optical information processings, such as a laser beam printer and an optical disk, etc., and is increasing the importance recently. Especially, grid matching of the material of 0.5(AlxGa1-x) In0.5P system is carried out to GaAs which is a good substrate material, and since it can obtain the laser beam which has the arbitrary wavelength within the limits of 0.68 to 0.56 micrometers by changing composition x, it attracts attention.

[0003] Hereafter, the semiconductor laser which has oscillation wavelength with reference to drawing 10 to the transverse-mode control type red field of the conventional double hetero structure is explained. This semiconductor laser is equipped with the n-GaAs buffer layer 2, the n-(aluminum0.7Ga0.3)0.51In0.49P clad layer 3, Ga0.51In0.49P barrier layer 4, the p-0.51(aluminum0.7Ga0.3) In0.49P clad layer 5, p-Ga0.51In0.49P layer 6, the n-GaAs current block layer 13, and the p-GaAs cap layer 9 on the n-GaAs substrate 1 at this order, as shown in drawing 10 . The p lateral electrode 10 is formed on the cap layer 9, and the n lateral electrode 11 is formed in the rear face of a substrate 1.

[0004] In this semiconductor laser, crystal-growth techniques, such as an organic-metal vapor growth (the MOVPE method), are used. The n-GaAs buffer layer 2, the n-(aluminum0.7Ga0.3)0.51In0.49P clad layer 3, Ga0.51In0.49P barrier layer 4, the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5, and p-Ga0.51In0.49P layer 6 are deposited one by one on the n-GaAs substrate 1 using such crystal-growth techniques.

[0005] Next, with phot lithography technique and etching technique, p-Ga0.51In0.49P layer 6 and the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 are etched in the shape of a trapezoid, and a stripe-like ridge is formed in the clad layer 5. The n-GaAs current block layer 13 is alternatively deposited on the exterior of a stripe after that using the MOVPE method etc., and the p-GaAs cap layer 9 is deposited further.

[0006] With such structure of semiconductor laser, the n-GaAs current block layer 13 can perform the constriction of a current. In case the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 is etched on a trapezoid, moreover, by optimizing a trapezoid height and trapezoid width of face The effective-refractive-index difference with which it is satisfied of the conditions of a single transverse mode can be given within and without a trapezoid-like stripe, and light can be effectively confined in the stripe-like ridge lower part of the clad layer 5 among barrier layers 4. The width of face of a stripe is about 5 micrometers typically.

[0007] [Problem(s) to be Solved by the Invention] However, with the structure of the conventional example, forbidden-band width of face uses parvus GaAs rather than the barrier layer as a current block layer. For this reason, this GaAs layer works as an absorption-of-light layer. Therefore, a loss of the light by absorption is large and waveguide loss alphai in case light guides the inside of the resonator of semiconductor laser becomes large with abbreviation 15cm-1. Consequently, the external differential quantum efficiency of semiconductor laser becomes small with about 60%. Moreover, at this semiconductor laser, kink level is about 12mW and the parvus. Although a kink is produced when the transverse mode changes, with the structure of drawing 10 , it is for the mode to become easy to change with the increases in an inrush current easily so greatly [the difference of the gain in a basic mode and the high order mode]. Since external differential quantum efficiency is small and the stability of the basic transverse mode is low, with the structure of the conventional example, it is hard to obtain the semiconductor laser with a high optical output.

[0008] The purpose of this invention is offering the semiconductor laser of high power with the high stability of the basic transverse mode which solves such a technical probrem and has high external differential quantum efficiency, and its manufacture technique.

[0009] [Means for Solving the Problem] The semiconductor laser of this invention is the laminated structure formed on the semiconductor substrate and this semiconductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the clad layer of the couple which sandwiches this barrier layer, and a current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. this current constriction layer It has the 1st-current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. this 1st-current block layer It is the semiconductor layer which has a refractive index higher than the refractive index of the clad layer of this couple, and it has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, and the above-mentioned purpose is attained by that.

[0010] In a certain example, the clad layer located among the clad layers of the aforementioned couple more nearly up than the aforementioned barrier layer has the stripe-like ridge prolonged along the orientation of a resonator of this semiconductor laser, and the aforementioned 1st-current block layer has covered fields other than this stripe-like ridge on this clad layer that has this stripe-like ridge.

[0011] In a certain example, the aforementioned current constriction layer is further equipped with the 2nd-current block layer prepared on the aforementioned 1st-current block layer, and this 2nd-current block layer is a semiconductor layer which has forbidden-band width of face larger than the forbidden-band width of face of the aforementioned barrier layer.

[0012] In a certain example, the cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a trapezoid.

[0013] In a certain example, the cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a rectangle.

[0014] In a certain example, the aforementioned semiconductor substrate is formed from GaAs, the aforementioned barrier layer is formed from GaInP, and the above 1st, the 2nd-current block layer, and the clad layer of the aforementioned couple are formed from AlGaInP.

[0015] One side of the clad layers of the aforementioned couple may have the 1st layer fraction and the 2nd layer fraction which are crowded on both sides of the aforementioned 1st-current block layer.

[0016] In a certain example, the aforementioned semiconductor substrate is formed from GaAs, the aforementioned barrier layer contains InGaAs layer, the clad layer of the aforementioned couple is formed from GaInP, and the aforementioned 1st semiconductor layer is formed from GaAs.

[0017] The aforementioned barrier layer may have multiplex quantum well structure. The manufacture technique of the semiconductor laser of this invention is the technique of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semiconductor substrate. this process The process which forms the 1st clad layer, the process which forms a barrier layer on this 1st clad layer, the process which forms the layer used as the 2nd clad layer on this barrier layer, and a part of this layer by etching alternatively The stripe-like ridge section prolonged in the orientation of a resonator of this semiconductor laser is formed in this layer. Among the process which forms the 2nd clad layer by it, and this 2nd clad layer, on fractions other than this stripe-like ridge section The process which forms the 1st semiconductor layer which has a refractive index higher than the refractive index of this 2nd clad layer, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The process which forms the 2nd semiconductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semiconductor layer is included, and the above-mentioned purpose is attained by that.

[0018] [Function] The current constriction layer of this invention is equipped with the 1st-current block layer formed in fields other than the field corresponding to the stripe-like predetermined field of a barrier layer. This 1st-current block layer has a refractive index higher than the refractive index of the clad layer of a couple, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[0019] The 1st-current block layer has the function which prevents that a current flows into a barrier layer. For this reason, a current is alternatively poured only into the predetermined field of the barrier layer corresponding to the field to which the 1st-current block layer does not exist. Consequently, a laser beam occurs only in the stripe-like predetermined field of a barrier layer. A part of this laser beam leaks in the vertical orientation from a barrier layer, and it reaches a clad layer and the 1st-current block layer. Since the 1st-current block layer has the refractive index

higher than the refractive index of a barrier layer, a laser beam leaks from a predetermined stripe-like field to longitudinal direction. Generally this ground is that it gathers in the field where light of a refractive index is high.

[0020] the laser beam oscillated in the basic level transverse mode, and the laser beam oscillated in the high order level transverse mode -- comparing -- a case -- the high order level transverse mode -- oscillating -- a laser beam -- the direction is widely distributed by longitudinal direction For this reason, in the semiconductor laser of this invention, the grade which leaks from a predetermined stripe-like field to longitudinal direction is stronger than the laser beam which the direction of the laser beam oscillated in the high order level transverse mode oscillates in the basic level transverse mode. For this reason, it emits and the laser beam oscillated in the high order level transverse mode stops contributing to a laser oscillation. In other words, the laser beam oscillated in the high order level transverse mode will have higher threshold gain by presence of the 1st-current block layer as compared with the laser beam oscillated in the basic level transverse mode. Consequently, only the laser beam oscillated in the basic level transverse mode can be obtained alternatively.

[0021] Moreover, since it has the forbidden-band width of face with the 1st-current block layer larger than the forbidden-band width of face of a barrier layer, the laser beam generated by the barrier layer is not absorbed by the 1st-current block layer. For this reason, a transmission loss of racer light is reduced as compared with the conventional semiconductor laser.

[0022] As explained above, the semiconductor laser of this invention can oscillate the laser beam of the basic level transverse mode by low transmission loss.

[0023]
[Example] (Example 1) The example of this invention is explained hereafter, referring to a drawing.

[0024] The cross section of the transverse-mode control type red semiconductor laser of one example of this invention is shown in drawing 1 .

[0025] This semiconductor laser has the double hetero structure which sandwiches Ga0.51In0.49P barrier layer 4 (thickness 600 ****** ** strike loam) through the n-GaAs buffer layer 2 on the n-GaAs substrate 1 in the n-(aluminum0.7Ga0.3)0.51In0.49P clad layer 3 and the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5, as shown in drawing 1 . In the upper part of the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5, it has p-Ga0.51In0.49P layer 6 (1000A in thickness), and a part of p-Ga0.51In0.49P layer 6 and p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 is processed into the trapezoid-like stripe-like ridge. In the clad layer 5, the thickness of fractions other than 1.3 micrometers and a stripe-like ridge fraction of the thickness of a stripe-like ridge fraction is 0.25 micrometers.

[0026] On the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 of both the sides of a stripe-like ridge, n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 of 700** and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 [0.7-micrometer] have accumulated. Furthermore, in the upper part of p-Ga0.51In0.49P layer 6 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8, it has the p-GaAs cap layer 9.

[0027] The width of face of the above-mentioned stripe-like ridge is the width of face which can take the large difference of the gain in the basic transverse mode and the high order mode, and the width of face has good about 7 micrometers. When extremely thinner than 7 micrometers, in

about 2 micrometers,.a leakage of the light to the outside of a stripe becomes large too much, the light which does not contribute to a laser oscillation increases, elevation of a threshold current and a loss become large, and a fall of external differential quantum efficiency is brought. Moreover, if stripe width of face becomes large too much, the difference of the gain in the basic transverse mode and the high order mode becomes small, or the ununiformity of injection of the carrier to Ga0.51In0.49P barrier layer 4 will be horizontal, and will arise, a fall of kink level will occur, and practical use will not be borne.

[0028] Moreover, although the cross-section configuration of a stripe-like ridge is a trapezoid in this example, this cross-section configuration may be a rectangle. In this case, it is desirable not to form layers 7 and 8 on the side face of a ridge.

[0029] The horizontal effective refractive index decided by the configuration of each class of this semiconductor laser is shown in drawing 2 . the effective refractive index inside a stripe-like ridge -- the effective refractive index of the exterior of 3.307 and a stripe-like ridge -- 3.329 -- it is -- external one -- 0.022 -- it is high This effective-refractive-index difference is brought by n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 of 700**, and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 [0.7-micrometer]. The difference of big gain arises between the basic transverse mode and the high order mode for this effective-refractive-index difference. For this reason, since it is hard to generate a kink even if it enlarges the amount of an inrush current, a high optical output can be obtained in the status that there is no kink.

[0030] It is shown in drawing 11 that the difference of big gain has arisen between a basic mode and the higher mode for the effective-refractive-index difference brought by n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 here. Drawing 11 is taken stripe width of face along a quadrature axis, and, as for it, the threshold gain gth is taken along an axis of ordinate. The difference of the threshold gain with primary mode (m= 1) was indicated about each of (a) this invention and the (b) conventional example as a basic mode (m= 0) and higher mode to this drawing. As shown in this drawing 11 , the higher mode [like / the difference of the threshold gain in a basic mode and primary mode is small, and / primary mode] it is tends to produce the laser of the conventional example of (b). On the other hand, the laser (b) of this invention has the large difference of the threshold gain in a basic mode and primary mode, and it is hard to produce the higher mode like primary mode.

[0031] Drawing 14 shows the relation between a drive current (CURRENT) and an optical output (OUTPUT POWER) about the semiconductor laser of this invention. The outgoing-radiation end face was coated with the layer of 6% of reflection factors, and the data shown in this graph were obtained about the semiconductor laser coated with other end faces with the layer of 83% of reflection factors. The cavity length of semiconductor laser is 500micro. Although the optical output is increasing linearly according to the increase in a drive current until an optical output exceeds about 65mW, after an optical output exceeds about 65mW, the grade of the increase in an optical output falls temporarily. As mentioned above, in a graph, such a fraction is called "kink." It is because the laser beam which that only the laser beam in a basic mode (m= 1) was oscillating has in the laser beam in modes (high order mode:m>=2) other than a basic mode and a basic mode when an optical output exceeds the level (it is called "kink level") begins to be intermingled that a kink occurs, when it is below in the level with an optical output. The semiconductor laser with higher kink level can stabilize for it and supply the laser beam in a basic mode in a high optical output. **** ** level becomes high so that the difference with the

threshold gain about the laser beam in the threshold gain about the laser beam in a basic mode (m= 1) and other modes (m>=2) is large.

[0032] Drawing 15 is a graph which shows the relation between the width of face of the stripe ridge of the clad layer 4, and the level of the optical output which a kink generates about the semiconductor laser of this invention which has the structure shown in drawing 1.

[0033] Each cavity length of the semiconductor laser used for measurement is 350 micrometers, and the ends side of each semiconductor laser is not coated with the reflective layer etc. As shown in drawing 15 , the semiconductor laser of this invention has high kink level as compared with the conventional semiconductor laser. This shows that the difference of the threshold gain of a basic mode (m= 1) and the threshold gain in other modes (m>=2) is large rather than it can set to the conventional semiconductor laser in the semiconductor laser of this invention.

[0034] Moreover, n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 block the current which flows from the p lateral electrode 10, they carry out the constriction of the current into the stripe-like ridge of the clad layer 5, and also possess the work which pours a current into the predetermined field of a barrier layer 4 by it.

[0035] In this invention, n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 of 700** and two kinds of 0.7-micrometer semiconductor layers of n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 are used in order to prepare a refractive-index difference within and without a trapezoid-like stripe. The layer 1st] semiconductor layer, i.e., the refractive index of n-(aluminum0.2Ga0.8)0.51In0.49P layer 7, is larger than the refractive index of the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5. A clad layer and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 with an almost equal refractive index are used for two-layer scale division. Light is influenced of the refractive index of only the material near the barrier layer 4. A stable effective refractive index can be obtained in the exterior of a stripe. The effective-refractive-index difference in desired stripe inside and outside is easily acquired by changing the thickness of n-(aluminum0.2Ga0.8)0.51In0.49P layer 7. That is, it will become small if an effective-refractive-index difference will become large if n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 becomes thick, and it becomes thin. The refractive-index difference in the stripe inside and outside is controlled by adjustment of the thickness of n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 in 0.01-0.05.

[0036] Moreover, although the 1st-layer aluminum composition was set to 0.2 here, even if it changes this aluminum composition, an effective-refractive-index difference can be changed. That is, if an effective-refractive-index difference will become large if aluminum composition becomes small, and aluminum composition becomes large, an effective-refractive-index difference will become small.

[0037] In order to give the same effective-refractive-index difference in one kind of semiconductor layer, there is no fluctuation of composition, and moreover, it needs to be thick, for example, it is necessary to deposit uniformly, 1 micrometers or more of the materials with it, for example, n-(aluminum0.55Ga0.45)0.51In0.49P layer. [a refractive index higher than that of the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 and, and] [very near] In this case, since light leaks deeply into n-(aluminum0.55Ga0.45)0.51In0.49P layer, light is influenced of the refractive index in the location distant distantly [barrier layer / 4]. Moreover, if it shifts from the set point, n-(aluminum0.55Ga0.45)0.51In0.49P layer composition, i.e., a refractive index, the effective refractive index in the inside and outside of a stripe will shift. Moreover, if the

thickness is thin, the light produced by Ga0.51In0.49P barrier layer 4 will be absorbed by the p-GaAs cap layer 9, and a loss of a light energy will arise. Therefore, a possibility that the stability when producing semiconductor laser and repeatability may become low arises. In order to make a desired effective-refractive-index difference with sufficient repeatability correctly, it is desirable to prepare two or more kinds of semiconductor layers.

[0038] The relation of the current poured into the optical output of this semiconductor laser and semiconductor laser is shown in drawing 3 . At this semiconductor laser, an optical output can be obtained in the status that there is no kink to about 30mW. Moreover, external differential quantum efficiency etaD of this semiconductor laser is as high as 85%. Since it gives a horizontal effective-refractive-index difference, it is because n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 are used. This two-layer forbidden-band width of face is larger than that of Ga0.51In0.49P barrier layer 4. Therefore, the light generated by Ga0.51In0.49P barrier layer 4 is not absorbed, therefore, as a result, waveguide loss alphai can obtain high external differential quantum efficiency small. Drawing 4 is an experimental result for investigating a waveguide loss, and is drawing showing the relation of the cavity length of inverse number 1 / etaD of external differential quantum efficiency, and semiconductor laser. A proportionality is between 1/etaD, and a cavity length, and a waveguide loss can be derived from this inclination with 4.2cm-1. Since a waveguide loss of the semiconductor laser of the conventional example is abbreviation 15cm-1, the semiconductor laser of this invention will take the value of 1 / 3 - 1/4. Therefore, it can explain that the external differential quantum efficiency of the semiconductor laser of this invention is high.

[0039] As an explanation of the semiconductor laser of this invention having a good property next, the result which measured the far field pattern of this invention is shown in drawing 12 .

[0040] (a) is the output luminous-intensity distribution to the angle of orientation level on each class of semiconductor laser, and (b) shows the output luminous-intensity distribution to the angle of orientation perpendicular to each class.

[0041] A small side lob is seen beside the main peaks of a far field pattern horizontal to each class of (a). Although this side lob is the characteristic feature of the semiconductor laser of this invention, it depends for the light from which this semiconductor laser is not oscillating by the higher mode, and leaked out of the ridge stripe.

[0042] Thus, it turns out that both the semiconductor laser of this invention is oscillated by the basic mode from the far field pattern.

[0043] In addition, drawing 13 explained plainly the main peaks shown in drawing 12 , and the side lob. It is a luminous-intensity distribution of orientation level on each class of semiconductor laser.

[0044] As stated above, the semiconductor laser of high power can be obtained from a high basic transverse-mode stability and high external differential quantum efficiency.

[0045] Below, from drawing 5 , drawing 9 is used and the production technique of this semiconductor laser is explained. First, the n-GaAs buffer layer 2, the n-(aluminum0.7Ga0.3)0.51In0.49P clad layer 3, Ga0.51In0.49P barrier layer 4, the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5, and p-Ga0.51In0.49P layer 6 are grown epitaxially on the n-GaAs substrate 1 using the crystal-growth technique, such as the MOVPE method, (drawing 5). After making SiO212 deposit on p-Ga0.51In0.49 P layer 6, a part of

$SiO_2$12, p-Ga0.51In0.49P layer 6, and p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 are processed into a trapezoid-like stripe using phot lithography technique and etching technique (drawing 6). A crystal growth is carried out on the p-(aluminum0.7Ga0.3)0.51In0.49P clad layer 5 of both the sides of a stripe, without making n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 deposit on $SiO_2$12 as a current block layer using the selective-growth technique of the MOVPE method, after processing it in the shape of a trapezoid (drawing 7). Then, $SiO_2$12 is removed and the crystal growth of the p-GaAs cap layer 9 is carried out (drawing 8). Finally Cr/Pt/Au is deposited on the p-GaAs contact layer 9, it considers as the p lateral electrode 10, Au/germanium/nickel is deposited on the n-GaAs substrate 1, and it considers as the n lateral electrode 11 (drawing 9).

[0046] By such manufacture technique, the transverse-mode control type red semiconductor laser which is shown in drawing 1 is producible.

[0047] In addition, although two kinds of semiconductor layers were used and explained in order to establish an effective-refractive-index difference within and without a trapezoid-like stripe, even if it uses three or more kinds, an effective refraction difference can be made from this example.

[0048] the above-mentioned example -- the effective refractive index inside a trapezoid-like stripe -- it of the exterior of a stripe -- 0.022 -- although it is made low, if the domain of this effective-refractive-index difference is 0.01 to 0.05, the effect of this invention is large However, if an effective-refractive-index difference changes, it must double with it and trapezoid-like stripe width of face must also be changed.

[0049] In addition, the effective refractive index of the fraction besides a stripe-like ridge is controllable by changing thickness h of the stripe-like ridge exterior of the clad layer 5, and the thickness of a layer 7. The domain of the thickness of 0.02-0.5 micrometers and the layer 8 has [the domain of the thickness of h / the domain of the thickness of 0.05-0.5 micrometers and the layer 7] desirable 0.3-1 micrometer.

[0050] Although the material which constitutes semiconductor laser from an above-mentioned example was specified, external differential quantum efficiency has a large clad layer also at the case of 0.51(AlzGa1-z) In0.49P (it is 0 <=z<=y<=1 here), and 0.51(AlyGa1-y) In0.49P and a barrier layer can produce easily the semiconductor laser of high power with a high transverse-mode stability.

[0051] Moreover, although the above-mentioned example explained the semiconductor laser which used AlGaInP for the material, it cannot be overemphasized that other materials of the effect of this invention are large. Not only an III-V group's semiconductor laser but the semiconductor laser of this effect of the invention which consists of an II-VI group's material is large.

[0052] Although the barrier layer of the above-mentioned example is formed of the monolayer of AlGaInP semiconductor, the barrier layer which has multiplex quantum well structure may be used. As such a barrier layer, for example A Ga0.44In0.56P well layer (8nm in thickness), A 0.51In0.49P barrier layer (5nm in thickness), (aluminum0.45Ga0.55) You may use a Ga0.44In0.56P well layer (8nm in thickness), a 0.51(aluminum0.45Ga0.55) In0.49P barrier layer (5nm in thickness), and the barrier layer included the Ga0.44In0.56P well layer (8nm in thickness). Since 0.5% of the compressive strain has arisen in three well layers, such a barrier

layer is called oval multiplex quantum well barrier layer. This multiplex quantum well barrier layer is sandwiched by 0.51(aluminum0.45Ga0.55) In0.49P light closing ****** (10nm in thickness) of the couple which touches a clad layer.

[0053] (Example 2) With reference to view 16 , other semiconductor laser by this invention is explained.

[0054] This semiconductor laser has the laminated structure formed on the n-GaAs substrate 61 and the n-GaAs substrate 61. A laminated structure in an order from the side near the n-GaAs substrate 61 The n-Ga0.51In0.49P 1st clad layer 62, the GaAs 1st light closing ****** (Thickness:1.5micrometer) 63, the deformation amount child well barrier layer 64, GaAs 2nd light closing ****** (thickness:0.01micrometer) 65, the p-Ga0.51In0.49P 2nd clad layer 66, the n-GaAs current block layer (thickness:0.15micrometer) 67, a p-GaAs cap layer (Thickness:0.01micrometer) (Thickness:3micrometer) 68 is included. The p lateral electrode 69 is formed on the p-GaAs cap layer 68 of a laminated structure, and the n lateral electrode 70 is formed in the rear face of the n-GaAs substrate 61.

[0055] The deformation amount child well barrier layer 64 has the quantum well structure which In0.2Ga0.8As 1st well layer (thickness:7nm) 64a, GaAs barrier layer (thickness:10nm) 64b, and In0.2Ga0.8As 2nd well layer (thickness:7nm) 64c form.

[0056] The p-Ga0.51In0.49P 2nd clad layer 66 is divided into 1st layer partial (thickness:0.2micrometer) 66a which touches optical closing ******, and 2nd layer partial (thickness:1.5micrometer) 66b which touches the p-GaAs cap layer 68. The n-GaAs current block layer 67 is located between 1st layer partial 66a of the p-Ga0.51In0.49P 2nd clad layer 66, and 2nd layer partial 66b.

[0057] The n-GaAs current block layer 67 is formed in fields other than the field corresponding to the predetermined field (current injection field) of the shape of a stripe of the deformation amount child well barrier layer 64. In other words, the n-GaAs current block layer 67 has stripe-like opening to the field corresponding to the current injection field of the deformation amount child well barrier layer 64. Width-of-face W of opening has specified the width of face of a current injection field. Although this width-of-face w is 6 micrometers typically, various values may be chosen from about 3 micrometers in the domain of about 8 micrometers. The n-GaAs current block layer 64 has a refractive index higher than the refractive index of the p-Ga0.51In0.49P 2nd clad layer 66, and has forbidden-band width of face larger than the forbidden-band width of face of a barrier layer 64.

[0058] The effective-refractive-index difference in the inside and outside of a stripe-like current injection field is controllable by adjusting thickness h of 1st layer partial 66a of the p-Ga0.51In0.49P 2nd clad layer 66, and thickness d of the n-GaAs current block layer 67. The thickness of 1st layer partial 66a of the p-Ga0.51In0.49P 2nd clad layer 66 may be chosen in the domain of about 0.05 to about 0.5 micrometers, and the thickness of the n-GaAs current block layer 67 may be chosen within the limits of about 0.02 to about 0.5 micrometers.

[0059] Also in the semiconductor laser of this example, the same effect as the semiconductor laser of this invention which has the structure mentioned above is acquired.

[0060] As the above-mentioned clad layer, you may use an AlxGa1-xAs (0.2<=x<=0.7) layer or (AlxGa1-x) 0.51In0.49P (0<=x<=1) layer. (AlxGa1-x) When 0.51In0.49P (0<=x<=1) layer is used for a clad layer, it is enabled to make the hetero barrier height between a barrier layer and a

clad layer higher than the height in this example. For this reason, the semiconductor laser which can operate stably at an elevated temperature is offered by adopting such a clad layer.

[0061] [Effect of the Invention] According to the semiconductor laser of this invention, to the exterior of the stripe of the clad layer of (1) semiconductor laser, the waveguide loss with a high and refractive index since a loss of a light according to absorption since a semiconductor layer larger than the forbidden-band width of face of a barrier layer is provided at least is small can be made small, and external differential quantum efficiency can obtain the semiconductor laser of the high power with the high stability of the basic transverse mode highly from the above-mentioned clad layer.

[0062] The process which carries out the laminating of the 1st clad layer, a barrier layer, and the 2nd clad layer one by one on (2) semiconductor substrate according to the manufacture technique of the semiconductor laser of this invention, A part of 2nd clad layer on the 2nd clad layer of the process processed into a trapezoid-like stripe, and the exterior of this stripe It has the process which carries out the laminating of at least two or more kinds of semiconductor layers in order to prevent injection of a current. Since it has the refractive index from which the two or more aforementioned kinds of semiconductor layers are different, a waveguide loss of light can be made small and external differential quantum efficiency can produce easily the semiconductor laser of the high power with the high stability of the basic transverse mode with sufficient repeatability highly.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The cross section of the transverse-mode control type red semiconductor laser of the example of this invention

[Drawing 2] Drawing showing an effective refractive index horizontal to the layer of the semiconductor laser of the example of this invention

[Drawing 3] Drawing showing the optical output of the semiconductor laser of the example of this invention, and the relation of a current

[Drawing 4] Drawing showing the relation between inverse number 1 / etaD of external differential quantum efficiency, and a cavity length in drawing for explaining the effect of this invention

[Drawing 5] The 1st order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 6] The 2nd order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 7] The 3rd order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 8] The 4th order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 9] The 5th order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 10] The cross section of the red semiconductor laser of the conventional example

[Drawing 11] Drawing explaining the difference of the threshold gain in this invention, the basic mode of the conventional example, and primary mode

[Drawing 12] Drawing showing the far field pattern of the semiconductor laser of this invention

[Drawing 13] Drawing showing the far field pattern of orientation level on each class of the semiconductor laser of this invention

[Drawing 14] Drawing showing the relation between the drive current of semiconductor laser, and an optical output which prepared the coating layer of 6% of reflection factors at the outgoing-radiation end face, and prepared 83% of the coating layer in other end faces in drawing showing the property of the semiconductor laser of this invention

[Drawing 15] Drawing showing the relation of the optical output which generates stripe width of face and a kink about the semiconductor laser of this invention

[Drawing 16] The cross section of the transverse-mode control type semiconductor laser of another example of this invention

[Description of Notations]
1 N-GaAs Substrate
2 N-GaAs Buffer Layer
3 N-(Aluminum0.7Ga0.3)0.51In0.49P Clad Layer
4 Ga0.51In0.49P Barrier Layer
5 P-(Aluminum0.7Ga0.3)0.51In0.49P Clad Layer
6 P-Ga0.51In0.49P Layer
7 N-(Aluminum0.2Ga0.8)0.51In0.49P Layer
8 N-(Aluminum0.7Ga0.3)0.51In0.49P Layer
9 P-GaAs Cap Layer
10 P Lateral Electrode
11 N Lateral Electrode
12 SiO2
13 N-GaAs Current Block Layer
61 N-GaAs Substrate
62 N-Ga0.51In0.49P Clad Layer
63 GaAs Light Closing ******
64 Deformation Amount Child Well Barrier Layer
64a In0.2Ga0.8As -- a well -- a layer
64b GaAs barrier layer
64c In0.2Ga0.8As -- a well -- a layer
65 GaAs Light Closing ******
66 P-Ga0.51In0.49P Clad Layer
66a The 1st layer which touches optical closing ******
66b The 2nd layer which touches the p-GaAs cap layer 68
67 N-GaAs Current Block Layer
68 P-GaAs Cap Layer
69 P Lateral Electrode
70 N Lateral Electrode

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(54) SEMICONDUCTOR LASER AND FABRICATION THEREOF

(57) Abstract:
PURPOSE: To provide a high output semiconductor laser having oscillation wavelength in visible light region in which differential quantum efficiency is enhanced while enhancing the stability of transverse mode.
CONSTITUTION: A p-(Al0.7Ga0.3)0.51In0.49 clad layer 5 of semiconductor laser is partially formed into a trapezoidal stripe. An n-(Al0.2Ga0.8)0.51In0.49P layer 7 and an n-(Al0.7Ga0.3)0.51In0.49P layer 8 are deposited on a p-(Al0.7Ga0.3)0.51In0.49P clad layer 5 on the outside of the stripe. Effective refractive index in the trapezoidal stripe is set lower by 0.02 than that on the outside of the stripe.

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CLAIMS
[Claim(s)]

[Claim 1] It is the laminated structure formed on the semi-conductor substrate and this semi-conductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the cladding layer of the pair which sandwiches this barrier layer, and a

current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. This current constriction layer It has the 1st current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. This 1st current block layer Semiconductor laser which is the semi-conductor layer which has a refractive index higher than the refractive index of the cladding layer of this pair, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[Claim 2] It is the semiconductor laser to which said 1st current block layer has covered fields other than this stripe-like ridge on this cladding layer that has this stripe-like ridge by being semiconductor laser according to claim 1, and the cladding layer located among the cladding layers of said pair more nearly up than said barrier layer having the stripe-like ridge prolonged along the direction of a resonator of this semiconductor laser.

[Claim 3] Said current constriction layer is semiconductor laser according to claim 2 which is the semi-conductor layer which is further equipped with the 2nd current block layer prepared on said 1st current block layer, and has forbidden-band width of face with this 2nd current block layer larger than the forbidden-band width of face of said barrier layer.

[Claim 4] Semiconductor laser according to claim 3 whose cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a trapezoid.

[Claim 5] Semiconductor laser according to claim 3 whose cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a rectangle.

[Claim 6] It is the semiconductor laser according to claim 3 in which said semi-conductor substrate is formed in from GaAs, said barrier layer is formed in from GaInP, and said 1st and 2nd current block layer and the cladding layer of said pair are formed from AlGaInP.

[Claim 7] Said barrier layer is semiconductor laser according to claim 1 which has multiplex quantum well structure.

[Claim 8] One side of the cladding layers of said pair is semiconductor laser according to claim 1 which has the 1st layer part and the 2nd layer part which are crowded on both sides of said 1st current block layer.

[Claim 9] It is the semiconductor laser according to claim 8 in which said semi-conductor substrate is formed in from GaAs, said barrier layer contains the InGaAs layer in, the cladding layer of said pair is formed in from GaInP, and said 1st semi-conductor layer is formed from GaAs.

[Claim 10] Said barrier layer is semiconductor laser according to claim 8 which has multiplex quantum well structure.

[Claim 11] It is the approach of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semi-conductor substrate. This process [etch / these some film / the process which forms the 1st cladding layer, the process which forms a barrier layer on this 1st cladding layer, the process which forms the film used as the 2nd cladding layer on this barrier layer, and / furthermore, / alternatively] The stripe-like ridge section prolonged in the direction of a resonator of this semiconductor laser is formed in this film. The process which forms the 2nd cladding layer by it, and among this 2nd cladding layer, on parts other than this stripe-like ridge section The process which forms the 1st semi-conductor layer which has a refractive index higher than the refractive index of this 2nd cladding layer, and has

forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The manufacture approach of the semiconductor laser which includes the process which forms the 2nd semi-conductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semi-conductor layer.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001] [Industrial Application] Luminous efficiency of this invention is high and it relates to the semiconductor laser and its manufacture approach of the high power excellent in the stability of the basic transverse mode.

[0002] [Description of the Prior Art] The semiconductor laser which produces laser oscillation and emits light in a light field has applications, such as the light sources for optical information processing, such as a laser beam printer and an optical disk, and is increasing the importance recently. Especially, lattice matching of the ingredient of 0.5(AlxGa 1-x) In0.5P system is carried out to GaAs which is a good substrate ingredient, and since it can obtain the laser beam which has the wavelength of the arbitration within the limits of 0.68 to 0.56 micrometers by changing presentation x, it attracts attention.

[0003] Hereafter, the semiconductor laser which has oscillation wavelength with reference to drawing 10 to the red field of the transverse-mode control mold of the conventional double hetero structure is explained. This semiconductor laser is equipped with the n-GaAs buffer layer 2, the n-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 3, Ga0.51In0.49P barrier layer 4, the p-0.51(aluminum0.7Ga0.3) In0.49P cladding layer 5, p-Ga0.51In0.49P layer 6, the n-GaAs current block layer 13, and the p-GaAs cap layer 9 on the n-GaAs substrate 1 at this order, as shown in drawing 10 . The p lateral electrode 10 is formed on the cap layer 9, and the n lateral electrode 11 is formed in the rear face of a substrate 1.

[0004] In this semiconductor laser, crystal growth techniques, such as metal-organic chemical vapor deposition (MOVPE law), are used. The sequential deposition of the n-GaAs buffer layer 2, the n-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 3, Ga0.51In0.49P barrier layer 4, the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5, and p-Ga0.51In0.49P layer 6 is carried out on the n-GaAs substrate 1 using these crystal growth techniques.

[0005] Next, with a phot lithography techniques and an etching technique, p-Ga0.51In0.49P layer 6 and the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 are etched into trapezoidal shape, and a stripe-like ridge is formed in a cladding layer 5. The n-GaAs current block layer 13 is alternatively deposited on the exterior of a stripe using the MOVPE method etc. after that, and the p-GaAs cap layer 9 is deposited further.

[0006] With the structure of such semiconductor laser, the n-GaAs current block layer 13 can perform the constriction of a current. In case the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 is etched on a trapezoid, moreover, by optimizing trapezoid height and width of face The effective-refractive-index difference with which are satisfied of the conditions of single transverse mode can be given within and without the stripe of trapezoidal shape, and light can be effectively confined in the stripe-like ridge lower part of a cladding layer 5 among barrier layers 4. The width of face of a stripe is about 5 micrometers typically.

[0007] [Problem(s) to be Solved by the Invention] However, with the structure of the conventional example, GaAs with forbidden-band width of face smaller than a barrier layer is used as a current block layer. For this reason, this GaAs layer works as an absorption-of-light layer. Therefore, loss of the light by absorption is large and guided wave loss alphai in case light guides the inside of the resonator of semiconductor laser becomes large with abbreviation 15cm-1. Consequently, the external differential quantum efficiency of semiconductor laser becomes small with about 60%. Moreover, in this semiconductor laser, kink level is as small as about 12mW. Although a kink is produced when the transverse mode changes, with the structure of drawing 10 , it is for the mode to become easy to change with the increments in an inrush current easily so greatly [the difference of the gain in a basic mode and the high order mode]. Since external differential quantum efficiency is small and the stability of the basic transverse mode is low, with the structure of the conventional example, it is hard to obtain semiconductor laser with a high optical output.

[0008] The purpose of this invention is offering the semiconductor laser of high power with the high stability of the basic transverse mode which solves such a technical problem and has high external differential quantum efficiency, and its manufacture approach.

[0009] [Means for Solving the Problem] The semiconductor laser of this invention is the laminated structure formed on the semi-conductor substrate and this semi-conductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the cladding layer of the pair which sandwiches this barrier layer, and a current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. This current constriction layer It has the 1st current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. This 1st current block layer It is the semi-conductor layer which has a refractive index higher than the refractive index of the cladding layer of this pair, and it has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, and the above-mentioned purpose is attained by that.

[0010] In a certain example, the cladding layer located among the cladding layers of said pair more nearly up than said barrier layer has the stripe-like ridge prolonged along the direction of a resonator of this semiconductor laser, and said 1st current block layer has covered fields other than this stripe-like ridge on this cladding layer that has this stripe-like ridge.

[0011] In a certain example, said current constriction layer is further equipped with the 2nd current block layer prepared on said 1st current block layer, and this 2nd current block layer is a semi-conductor layer which has forbidden-band width of face larger than the forbidden-band width of face of said barrier layer.

[0012] In a certain example, the cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a trapezoid.

[0013] In a certain example, the cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a rectangle.

[0014] In a certain example, said semi-conductor substrate is formed from GaAs, said barrier layer is formed from GaInP, and said 1st and 2nd current block layer and the cladding layer of said pair are formed from AlGaInP.

[0015] One side of the cladding layers of said pair may have the 1st layer part and the 2nd layer part which are crowded on both sides of said 1st current block layer.

[0016] In a certain example, said semi-conductor substrate is formed from GaAs, said barrier layer contains the InGaAs layer, the cladding layer of said pair is formed from GaInP, and said 1st semi-conductor layer is formed from GaAs.

[0017] Said barrier layer may have multiplex quantum well structure. The manufacture approach of the semiconductor laser of this invention is an approach of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semi-conductor substrate. This process The process which forms the 1st cladding layer, the process which forms a barrier layer on this 1st cladding layer, the process which forms the film used as the 2nd cladding layer on this barrier layer, and by etching these some film alternatively The stripe-like ridge section prolonged in the direction of a resonator of this semiconductor laser is formed in this film. The process which forms the 2nd cladding layer by it, and among this 2nd cladding layer, on parts other than this stripe-like ridge section The process which forms the 1st semi-conductor layer which has a refractive index higher than the refractive index of this 2nd cladding layer, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The process which forms the 2nd semi-conductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semi-conductor layer is included, and the above-mentioned purpose is attained by that.

[0018] [Function] The current constriction layer of this invention is equipped with the 1st current block layer formed in fields other than the field corresponding to the stripe-like predetermined field of a barrier layer. This 1st current block layer has a refractive index higher than the refractive index of the cladding layer of a pair, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[0019] The 1st current block layer has the function which prevents that a current flows into a barrier layer. For this reason, a current is alternatively poured only into the predetermined field of the barrier layer corresponding to the field to which the 1st current block layer does not exist. Consequently, a laser beam occurs only in the stripe-like predetermined field of a barrier layer. A part of this laser beam leaks in the vertical direction from a barrier layer, and it reaches a cladding layer and the 1st current block layer. Since the 1st current block layer has the refractive index higher than the refractive index of a barrier layer, a laser beam leaks from a predetermined stripe-like field to a longitudinal direction. Generally this reason is that light gathers in the field where a refractive index is high.

[0020] the laser beam oscillated in the basic level transverse mode, and the laser beam oscillated in the high order level transverse mode -- comparing -- a case -- the high order level transverse mode -- oscillating -- a laser beam -- the direction is widely distributed by the longitudinal direction. For this reason, in the semiconductor laser of this invention, extent which leaks from a predetermined stripe-like field to a longitudinal direction is stronger than the laser beam which the direction of the laser beam oscillated in the high order level transverse mode oscillates in the basic level transverse mode. It emits and the laser beam oscillated in the high order level transverse mode stops for this reason, contributing to laser oscillation. In other words, the laser beam oscillated in the high order level transverse mode will have higher threshold gain by existence of the 1st current block layer as compared with the laser beam oscillated in the basic level transverse mode. Consequently, only the laser beam oscillated in the basic level transverse mode can be obtained alternatively.

[0021] Moreover, since it has forbidden-band width of face with the 1st current block layer larger than the forbidden-band width of face of a barrier layer, the laser beam generated in the barrier layer is not absorbed by the 1st current block layer. For this reason, propagation loss of racer light is reduced as compared with the conventional semiconductor laser.

[0022] As explained above, the semiconductor laser of this invention can oscillate the laser beam of the basic level transverse mode by low propagation loss.

[0023] [Example] (Example 1) The example of this invention is explained hereafter, referring to a drawing.

[0024] The sectional view of the red semiconductor laser of the transverse-mode control mold of one example of this invention is shown in drawing 1 .

[0025] This semiconductor laser has the double hetero structure which sandwiches Ga0.51In0.49P barrier layer 4 (600A in thickness) through the n-GaAs buffer layer 2 by the n-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 3 and the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 on the n-GaAs substrate 1, as shown in drawing 1 . In the upper part of the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5, it has p-Ga0.51In0.49P layer 6 (1000A in thickness), and a part of p-Ga0.51In0.49P layer 6 and p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 is processed into the stripe-like ridge of trapezoidal shape. In a cladding layer 5, the thickness of parts other than 1.3 micrometers and a stripe-like ridge part of the thickness of a stripe-like ridge part is 0.25 micrometers.

[0026] On the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 of both the sides of a stripe-like ridge, n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 [700A] and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 [0.7-micrometer] have accumulated. Furthermore, in the upper part of p-Ga0.51In0.49P layer 6 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8, it has the p-GaAs cap layer 9.

[0027] The width of face of the above-mentioned stripe-like ridge is the width of face which can take the large difference of the gain in the basic transverse mode and the high order mode, and the width of face has good about 7 micrometers. When extremely thinner than 7 micrometers, in the case of about 2 micrometers, leakage of the light to the outside of a stripe becomes large too much, the light which does not contribute to laser oscillation increases, the rise of a threshold current and loss become large, and decline in external differential quantum efficiency is brought about. Moreover, if stripe width of face becomes large too much, the difference of the gain in the basic transverse mode and the high order mode becomes small, or the ununiformity of impregnation of the carrier to Ga0.51In0.49P barrier layer 4 will be horizontal, and will arise, the fall of kink level will occur, and practical use will not be borne.

[0028] Moreover, although the cross-section configuration of a stripe-like ridge is a trapezoid in this example, this cross-section configuration may be a rectangle. In that case, it is desirable not to form layers 7 and 8 on the side face of a ridge.

[0029] The horizontal effective refractive index decided by the configuration of each class of this semiconductor laser is shown in drawing 2 . the effective refractive index inside a stripe-like ridge -- the effective refractive index of the exterior of 3.307 and a stripe-like ridge -- 3.329 -- it is -- external one -- 0.022 -- it is high. This effective-refractive-index difference is brought about by n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 [700A] and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 [0.7-micrometer]. The difference of big gain arises between the basic transverse mode

and the high order mode because of this effective-refractive-index difference. For this reason, since it is hard to generate a kink even if it enlarges the amount of an inrush current, a high optical output can be obtained in the condition that there is no kink.

[0030] It is shown in drawing 11 that the difference of big gain has arisen between a basic mode and the higher mode because of the effective-refractive-index difference brought about by n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 here. Drawing 11 takes stripe width of face along an axis of abscissa, and takes the threshold gain gth along an axis of ordinate. The difference of threshold gain with the primary mode (m= 1) was indicated about each of (a) this invention and the (b) conventional example as a basic mode (m= 0) and the higher mode to this drawing. The higher mode [like / the difference of the threshold gain in a basic mode and the primary mode is small, and / the primary mode] it is tends to produce the laser of the conventional example of (b) so that this drawing 11 may show. On the other hand, the laser (b) of this invention has the large difference of the threshold gain in a basic mode and the primary mode, and cannot produce the higher mode like the primary mode easily.

[0031] Drawing 14 shows the relation between a drive current (CURRENT) and an optical output (OUTPUT POWER) about the semiconductor laser of this invention. Coating of the outgoing radiation end face was carried out with the film of 6% of reflection factors, and the data shown in this graph were obtained about the semiconductor laser to which coating of other end faces was carried out with the film of 83% of reflection factors. The cavity length of semiconductor laser is 500micro. The optical output is increasing linearly according to the increment in a drive current until an optical output exceeds about 65mW, but after an optical output exceeds about 65mW, extent of the increment in an optical output falls temporarily. As mentioned above, in a graph, such a part is called "kink." When it is below in level with an optical output, a kink occurs, because the laser beam which that only the laser beam in a basic mode (m= 1) was oscillating has in the laser beam in the modes other than a basic mode (the high order mode: m>=2) and a basic mode when an optical output exceeds the level (it is called "kink level") begins to be intermingled. Semiconductor laser with higher kink level can stabilize for it and supply the laser beam in a basic mode in a high optical output. KIN ** level becomes high, so that the difference of the threshold gain about the laser beam in a basic mode (m= 1) and the threshold gain about the laser beam in other modes (m>=2) is large.

[0032] Drawing 15 is a graph which shows the relation between the width of face of the stripe ridge of a cladding layer 4, and the level of the optical output which a kink generates about the semiconductor laser of this invention which has the structure shown in drawing 1 .

[0033] Each cavity length of the semiconductor laser used for measurement is 350 micrometers, and coating of the reflective film etc. is not carried out to the both-ends side of each semiconductor laser. The semiconductor laser of this invention has high kink level as compared with the conventional semiconductor laser so that drawing 15 may show. This shows that the difference of the threshold gain of a basic mode (m= 1) and the threshold gain in other modes (m>=2) is large rather than it can set to the conventional semiconductor laser in the semiconductor laser of this invention.

[0034] Moreover, n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 block the current which flows from the p lateral electrode 10, they carry out the constriction of the current into the stripe-like ridge of a cladding

layer 5, and also possess the work which pours a current into the predetermined field of a barrier layer 4 by it.

[0035] In this invention, 700A n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and two kinds of 0.7-micrometer semi-conductor layers of n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 are used in order to prepare a refractive-index difference within and without the stripe of trapezoidal shape. The layer [1st] semi-conductor layer, i.e., the refractive index of n-(aluminum0.2Ga0.8)0.51In0.49P layer 7, is larger than the refractive index of the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5. A cladding layer and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 with an almost equal refractive index are used for the two-layer eye. Light is influenced of the refractive index of only the ingredient near the barrier layer 4. A stable effective refractive index can be obtained in the exterior of a stripe. The effective-refractive-index difference in desired stripe inside and outside is easily acquired by changing the thickness of n-(aluminum0.2Ga0.8)0.51In0.49P layer 7. That is, it will become small if an effective-refractive-index difference will become large if n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 becomes thick, and it becomes thin. The refractive-index difference in the stripe inside and outside is controlled by adjustment of the thickness of n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 in 0.01-0.05.

[0036] Moreover, although the 1st-layer aluminum presentation was set to 0.2 here, even if it changes this aluminum presentation, an effective-refractive-index difference can be changed. That is, if an effective-refractive-index difference will become large if aluminum presentation becomes small, and aluminum presentation becomes large, an effective-refractive-index difference will become small.

[0037] the ingredient 0.49 with it, for example, n-(aluminum0.55Ga0.45)0.51In, -- the fluctuation of the presentation of P layers -- there is nothing -- homogeneity -- and it needs to be thick, for example, it is necessary to deposit 1 micrometers or more [a refractive index higher than that of the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 and, and] [very near in order to give the same effective-refractive-index difference in one kind of semi-conductor layer] In this case, since light leaks deeply into n-(aluminum0.55Ga0.45)0.51In0.49P layer, light is influenced of the refractive index in the location distant distantly [barrier layer / 4]. Moreover, if it shifts from the set point, n-(aluminum0.55Ga0.45)0.51In0.49P layer a presentation, i.e., a refractive index, the effective refractive index in the inside and outside of a stripe will shift. Moreover, if the thickness is thin, the light produced in Ga0.51In0.49P barrier layer 4 will be absorbed by the p-GaAs cap layer 9, and loss of light energy will arise. Therefore, a possibility that the stability when producing semiconductor laser and repeatability may become low arises. In order to make a desired effective-refractive-index difference with sufficient repeatability correctly, it is desirable to prepare two or more kinds of semi-conductor layers.

[0038] The optical output of this semiconductor laser and the relation of the current poured into semiconductor laser are shown in drawing 3 . At this semiconductor laser, an optical output can be obtained in the condition that there is no kink to about 30mW. Moreover, external differential-quantum-efficiency etaD of this semiconductor laser is as high as 85%. Since a horizontal effective-refractive-index difference is given, it is because n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 are used. This two-layer forbidden-band width of face is larger than that of Ga0.51In0.49P barrier layer 4. Therefore, the light generated in Ga0.51In0.49P barrier layer 4 is not absorbed,

therefore, as a result, guided wave loss alphai can acquire high external differential quantum efficiency small. Drawing 4 is an experimental result for investigating guided wave loss, and is drawing showing the relation of the cavity length of inverse number 1 / etaD of external differential quantum efficiency, and semiconductor laser. Proportionality is between 1/etaD and cavity length, and guided wave loss can be derived from this inclination with 4.2cm-1. Since guided wave loss of the semiconductor laser of the conventional example is abbreviation 15cm-1, the semiconductor laser of this invention will take the value of 1 / 3 - 1/4. Therefore, it can explain that the external differential quantum efficiency of the semiconductor laser of this invention is high.

[0039] As explanation of the semiconductor laser of this invention having a good property next, the result of having measured the far field pattern of this invention is shown in drawing 12 .

[0040] (a) is output luminous-intensity distribution over the include angle of a direction level on each class of semiconductor laser, and (b) shows the output luminous-intensity distribution over the include angle of a direction perpendicular to each class.

[0041] Small Said Rob is seen beside the peak of Maine of a far field pattern horizontal to each class of (a). Although this Said Rob is the description of the semiconductor laser of this invention, it is not that this semiconductor laser is oscillating by the higher mode, and depends for the light which leaked out of the ridge stripe.

[0042] Thus, it turns out that both the semiconductor laser of this invention is oscillated by the basic mode from the far field pattern.

[0043] In addition, drawing 13 explained plainly the peak of Maine shown in drawing 12 , and Said Rob. It is luminous-intensity distribution of a direction level on each class of semiconductor laser.

[0044] As stated above, the semiconductor laser of high power can be obtained from high basic transverse-mode stability and high external differential quantum efficiency.

[0045] Below, drawing 9 is used from drawing 5 R> 5, and the production approach of this semiconductor laser is explained. First, the n-GaAs buffer layer 2, the n-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 3, Ga0.51In0.49P barrier layer 4, the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5, and p-Ga0.51In0.49P layer 6 are grown epitaxially on the n-GaAs substrate 1 using the crystal growth approaches, such as the MOVPE method, (drawing 5). After making SiO212 deposit on p-Ga0.51In0.49 P layer 6, a part of SiO212, p-Ga0.51In0.49P layer 6, and p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 are processed into the stripe of trapezoidal shape using a phot lithography techniques and an etching technique (drawing 6 R> 6). MOVPE after processing trapezoidal shape -- crystal growth is carried out on the p-(aluminum0.7Ga0.3)0.51In0.49P cladding layer 5 of both the sides of a stripe, without making n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 deposit on SiO212 as a current block layer using the selective growth technique of law (drawing 7). Then, SiO212 is removed and crystal growth of the p-GaAs cap layer 9 is carried out (drawing 8). Finally Cr/Pt/Au is deposited on the p-GaAs contact layer 9, it considers as the p lateral electrode 10, Au/germanium/nickel is deposited on the n-GaAs substrate 1, and it considers as the n lateral electrode 11 (drawing 9).

[0046] By such manufacture approach, the red semiconductor laser of a transverse-mode control mold as shown in drawing 1 is producible.

[0047] In addition, by this example, in order to establish an effective-refractive-index difference within and without the stripe of trapezoidal shape, two kinds of semi-conductor layers were used and explained, but even if it uses three or more kinds, an effective refraction difference can be made.

[0048] the above-mentioned example -- the effective refractive index inside the stripe of trapezoidal shape -- it of the exterior of a stripe -- 0.022 -- although it is made low, if the range of this effective-refractive-index difference is 0.01 to 0.05, the effectiveness of this invention is large. However, if an effective-refractive-index difference changes, according to it, the stripe width of face of trapezoidal shape must also be changed.

[0049] In addition, the effective refractive index of the part besides a stripe-like ridge is controllable by changing thickness [of the stripe-like ridge exterior of a cladding layer 5] h, and the thickness of a layer 7. The range of the thickness of 0.02-0.5 micrometers and a layer 8 has [the range of the thickness of h / the range of the thickness of 0.05-0.5 micrometers and a layer 7] desirable 0.3-1 micrometer.

[0050] Although the ingredient which constitutes semiconductor laser from an above-mentioned example was specified, also by the case of 0.51(AlzGa1-z) In0.49P (here, it is 0 <=z<=y<=1), 0.51(AlyGa1-y) In0.49P and a barrier layer have large external differential quantum efficiency, and a cladding layer can produce easily the semiconductor laser of high power with high transverse-mode stability.

[0051] Moreover, although the above-mentioned example explained the semiconductor laser which used AlGaInP for the ingredient, it cannot be overemphasized that other ingredients have the large effectiveness of this invention. Not only an III-V group's semiconductor laser but the semiconductor laser of this effect of the invention which consists of an II-VI group's ingredient is large.

[0052] Although the barrier layer of the above-mentioned example is formed of the monolayer of an AlGaInP semi-conductor, the barrier layer which has multiplex quantum well structure may be used. As such a barrier layer, for example A Ga0.44In0.56P well layer (8nm in thickness), A 0.51In0.49P barrier layer (5nm in thickness), (aluminum0.45Ga0.55) A Ga0.44In0.56P well layer (8nm in thickness), a 0.51(aluminum0.45Ga0.55) In0.49P barrier layer (5nm in thickness), and the barrier layer included the Ga0.44In0.56P well layer (8nm in thickness) may be used. Since 0.5% of compressive strain has arisen in three well layers, such a barrier layer is called a distorted multiplex quantum well barrier layer. This multiplex quantum well barrier layer is sandwiched by the 0.51(aluminum0.45Ga0.55) In0.49P optical confinement layer (10nm in thickness) of the pair which touches a cladding layer.

[0053] (Example 2) With reference to drawing 16 , other semiconductor laser by this invention is explained.

[0054] This semiconductor laser has the laminated structure formed on the n-GaAs substrate 61 and the n-GaAs substrate 61. A laminated structure in an order from the side near the n-GaAs substrate 61 The n-Ga0.51In0.49P 1st cladding layer 62, the 1st optical confinement layer of GaAs (Thickness: 1.5 micrometers) 63, the deformation amount child well barrier layer 64, the 2nd optical confinement layer (thickness: 0.01 micrometers) 65 of GaAs, the p-Ga0.51In0.49P 2nd cladding layer 66, the n-GaAs current block layer (thickness: 0.15 micrometers) 67, a p-GaAs cap layer (Thickness: 0.01 micrometers) (Thickness: 3 micrometers) 68 is included. The p

lateral electrode 69 is formed on the p-GaAs cap layer 68 of a laminated structure, and the n lateral electrode 70 is formed in the rear face of the n-GaAs substrate 61.

[0055] The deformation amount child well barrier layer 64 has the quantum well structure which 1st well layer (thickness: 7nm) of In0.2Ga0.8As 64a, GaAs barrier layer (thickness: 10nm) 64b, and 2nd well layer (thickness: 7nm) of In0.2Ga0.8As 64c form.

[0056] The p-Ga0.51In0.49P 2nd cladding layer 66 is divided into 1st layer partial (thickness: 0.2 micrometers) 66a which touches an optical confinement layer, and 2nd layer partial (thickness: 1.5 micrometers) 66b which touches the p-GaAs cap layer 68. Between 1st layer partial 66a of the p-Ga0.51In0.49P 2nd cladding layer 66, and 2nd layer partial 66b, the n-GaAs current block layer 67 is located.

[0057] The n-GaAs current block layer 67 is formed in fields other than the field corresponding to the predetermined field (current impregnation field) of the shape of a stripe of the deformation amount child well barrier layer 64. In other words, the n-GaAs current block layer 67 has stripe-like opening to the field corresponding to the current impregnation field of the deformation amount child well barrier layer 64. The width of face W of opening has specified the width of face of a current impregnation field. Although this width of face w is 6 micrometers typically, various values may be chosen from about 3 micrometers in the range of about 8 micrometers. The n-GaAs current block layer 64 has a refractive index higher than the refractive index of the p-Ga0.51In0.49P 2nd cladding layer 66, and has forbidden-band width of face larger than the forbidden-band width of face of a barrier layer 64.

[0058] The effective-refractive-index difference in the inside and outside of a stripe-like current impregnation field is controllable by adjusting thickness [of 1st layer partial 66a of the p-Ga0.51In0.49P 2nd cladding layer 66] h, and thickness d of the n-GaAs current block layer 67. The thickness of 1st layer partial 66a of the p-Ga0.51In0.49P 2nd cladding layer 66 may be chosen from about 0.05 micrometers in the range of about 0.5 micrometers, and the thickness of the n-GaAs current block layer 67 may be chosen from about 0.02 micrometers within the limits of about 0.5 micrometers.

[0059] Also in the semiconductor laser of this example, the same effectiveness as the semiconductor laser of this invention which has the structure mentioned above is acquired.

[0060] As the above-mentioned cladding layer, an AlxGa1-xAs (0.2<=x<=0.7) layer or (AlxGa 1-x) 0.51In0.49P (0<=x<=1) layer may be used. (AlxGa 1-x) When 0.51In0.49P (0<=x<=1) layer is used for a cladding layer, it becomes possible to make the hetero barrier height between a barrier layer and a cladding layer higher than the height in this example. For this reason, the semiconductor laser which can operate to stability at an elevated temperature more is offered by adopting such a cladding layer.

[0061] [Effect of the Invention] According to the semiconductor laser of this invention, to the exterior of the stripe of the cladding layer of (1) semiconductor laser, since a semi-conductor layer with it is provided at least from the above-mentioned cladding layer, since loss of the light by absorption is small, guided wave loss can be made small, and external differential quantum efficiency can obtain the semiconductor laser of the extremely stable high power of the basic transverse mode highly. [a high and refractive index and] [larger than the forbidden-band width of face of a barrier layer]

[0062] The process which carries out the laminating of the 1st cladding layer, a barrier layer, and the 2nd cladding layer one by one on (2) semi-conductor substrate according to the manufacture approach of the semiconductor laser of this invention, A part of 2nd cladding layer on the 2nd cladding layer of the process processed into the stripe of trapezoidal shape, and the exterior of this stripe It has the process which carries out the laminating of at least two or more kinds of semi-conductor layers in order to prevent impregnation of a current. Since it has the refractive index from which said two or more kinds of semi-conductor layers differ, guided wave loss of light can be made small and external differential quantum efficiency can produce easily the semiconductor laser of the extremely stable high power of the basic transverse mode with sufficient repeatability highly.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The sectional view of the red semiconductor laser of the transverse-mode control mold of the example of this invention

[Drawing 2] Drawing showing an effective refractive index horizontal to the layer of the semiconductor laser of the example of this invention

[Drawing 3] Drawing showing the optical output of the semiconductor laser of the example of this invention, and the relation of a current

[Drawing 4] Drawing showing 1/etaD of inverse numbers of external differential quantum efficiency, and the relation of cavity length in drawing for explaining the effectiveness of this invention

[Drawing 5] The 1st order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 6] The 2nd order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 7] The 3rd order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 8] The 4th order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 9] The 5th order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 10] The sectional view of the red semiconductor laser of the conventional example

[Drawing 11] Drawing explaining the difference of the threshold gain in this invention, the basic mode of the conventional example, and the primary mode

[Drawing 12] Drawing showing the far field pattern of the semiconductor laser of this invention

[Drawing 13] Drawing showing the far field pattern of a direction level on each class of the semiconductor laser of this invention

[Drawing 14] Drawing showing the drive current of the semiconductor laser which prepared the coating film of 6% of reflection factors in the outgoing radiation end face, and prepared 83% of coating film in other end faces, and the relation of an optical output in drawing showing the property of the semiconductor laser of this invention

[Drawing 15] Drawing showing stripe width of face and the relation of the optical output which generates a kink about the semiconductor laser of this invention

[Drawing 16] The sectional view of the semiconductor laser of the transverse-mode control mold of another example of this invention

[Description of Notations]
1 N-GaAs Substrate
2 N-GaAs Buffer Layer
3 N-(Aluminum0.7Ga0.3)0.51In0.49P Cladding Layer
4 Ga0.51In0.49P Barrier Layer
5 P-(Aluminum0.7Ga0.3)0.51In0.49P Cladding Layer
6 P-Ga0.51In0.49P Layer
7 N-(Aluminum0.2Ga0.8)0.51In0.49P Layer
8 N-(Aluminum0.7Ga0.3)0.51In0.49P Layer
9 P-GaAs Cap Layer
10 P Lateral Electrode
11 N Lateral Electrode
12 SiO2
13 N-GaAs Current Block Layer
61 N-GaAs Substrate
62 N-Ga0.51In0.49P Cladding Layer
63 GaAs Optical Confinement Layer
64 Deformation Amount Child Well Barrier Layer
64a In0.2Ga0.8As -- a well -- a layer
64b GaAs barrier layer
64c In0.2Ga0.8As -- a well -- a layer
65 GaAs Optical Confinement Layer
66 P-Ga0.51In0.49P Cladding Layer
66a The 1st layer which touches an optical confinement layer
66b The 2nd layer which touches the p-GaAs cap layer 68
67 N-GaAs Current Block Layer
68 P-GaAs Cap Layer
69 P Lateral Electrode
70 N Lateral Electrode